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DEVOTED TO

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OF THE STATE OF PENNSYLVANIA,

FOR THE

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EDITORIAL.

ITEMS AND NOVELTIES.

The Commission on Water Supply of the City of Philadelphia.—The Commission of Civil Engineers appointed by the Mayor met together at the Franklin Institute, on the 29th of June, and organized by the election of W. Milnor Roberts, as Chairman. The ordinance of Councils makes it the duty of this commission to examine and report upon the present and future water supply of the city of Philadelphia. The commission consists of the following gentlemen: W. Milnor Roberts, C.E., of New York; Hon. Wm. J. McAlpine, C.E., of Albany; Col. Julius W. Adams, C.E., of Brooklyn; S. W. Roberts, C.E., of Philadelphia; Wm. E. Morris, C.E., of Philadelphia; who, according to the ordinance, act in conjunction with Dr. Wm. H. McFadden, Chief Engineer of the City Water Department.

We learn that these gentlemen, ever since their organization as a commission, have been almost constantly engaged in the performance of the very important and responsible duty which has been assigned to them. They have visited and examined all the pumping works

at Fairmount, Spring Garden, Belmont, Roxborough, Chestnut Hill, and Kensington, and the Fairmount, Belmont, Roxborough, Chestnut Hill, Mount Airy, Germantown, Lehigh Avenue and Corinthian reservoirs; also the large unfinished reservoir in East Park. They have also made special examinations of the Wissahickon Valley, of the Valley of the Perkiomen, and of the proposed reservoir site in that valley, in company with Mr. Birkinbine, former Chief Engineer of the Water Department, who recommended its construction, in reports made by him about ten years ago.

The members of the commission, by invitation of Mr. Gowen, President of the Reading Rail Road Company, who kindly placed special engines at their disposal, made a very satisfactory visit to the upper Schuylkill, accompanied by James F. Smith, Chief Engineer of the Schuylkill Navigation Co., who showed and explained the Company's reservoirs at Tumbling Run. They made an examination of the Delaware river, accompanied by Mayor Stokley, as far up as Beverly, a few miles above the city boundary, making special observations at all important sewage and creek outlets. Afterward, members of the commission examined the Delaware river above tide, particularly at New Hope, Easton, and the Delaware Water Gap. They visited Ewing's Spring, which is 2½ miles from New Hope. They also made an examination of the Schuylkill river, between Fairmount dam and Spring Mills, passing through the locks of the Navigation Company, and visited the fine spring near Spring Mills.

The commission have requested the Chief Engineer of the Water Department to have rapid surveys made from the Perkiomen, and from the vicinity of New Hope to the city, to enable them to judge correctly of the nature and extent of the obstacles in the way of possible lines of conduit. Meanwhile, the members, whether in session or otherwise, are almost constantly engaged in collecting and collating data to aid them in their investigations.

It is well known to those who are familiar with the water system of Philadelphia, that it is one of peculiar complication; owing not so much to the topography as to the comparatively late consolidation into one, of a number of separate municipal or civil corporations, each having its own water supply arrangement.

The object of the commission is to ascertain what is most advantageous for the immediate demands of the city; and, which is still more important, what is the best plan or plans for the future.

While much preliminary work has already been accomplished by the commission, some time will necessarily be required to arrange the various data, which are daily accumulating, as well as for their complete study and discussion before any definite conclusions can be reached.

We learn that at the request of the commission our fellow-townsman, Mr. Jas. Haworth, appeared before them and presented some views, in addition to those he has before made public in several pamphlets.

The Chief Engineer of the Water Department, and his assistants, have been kept busy in preparing statistics of various kinds, relating to the subject, for the use of the commission, and in making measurements of the flow of certain streams. It is obvious that the matter is in the hands of gentlemen competent to fulfill the duty assigned to them, and that they have entered upon their labors with a determination to make their investigations in the most thorough manner.

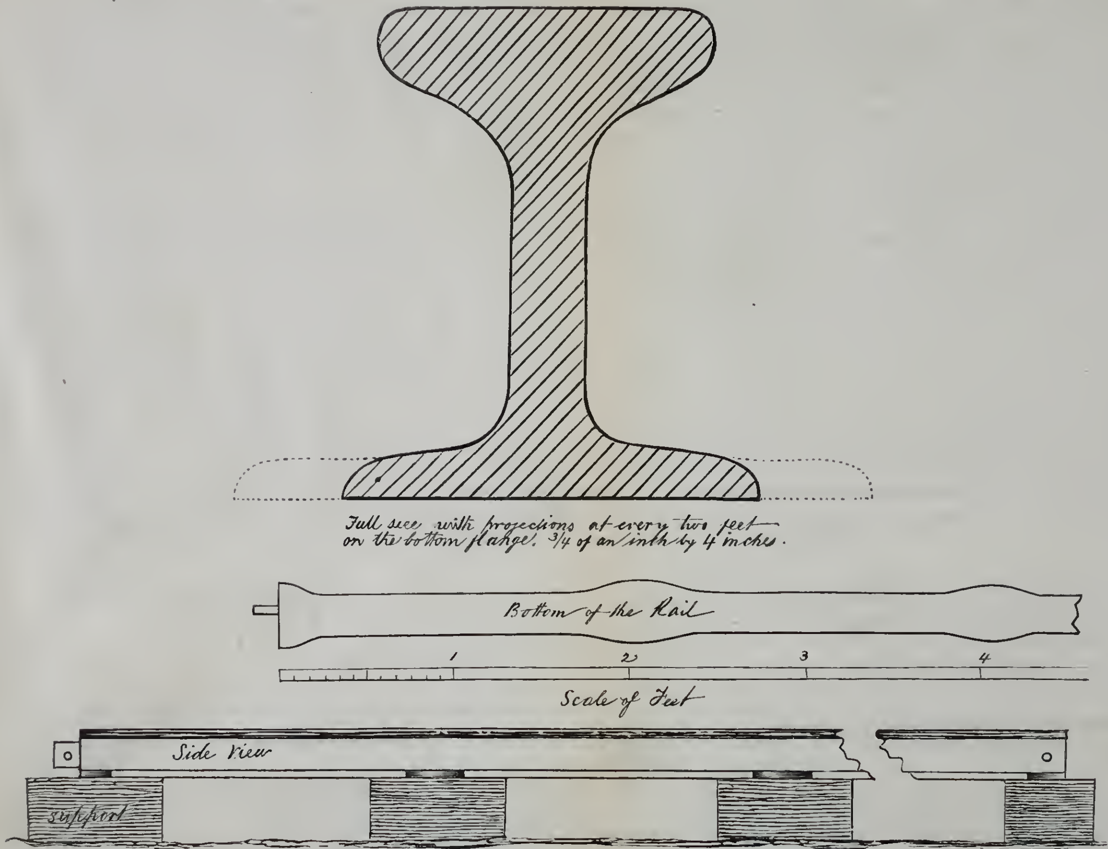
Edgerton's Oxy-Hydro-Carbon Light.—At the June meeting of the Institute, this invention was exhibited and described. It consists of a small copper vessel, placed immediately over the flame of a jet, arranged as in the ordinary oxy-hydrogen light and so connected with a reservoir that hydro-carbon oil can be fed into it as required. The heat of the flame converts the oil into vapor of high tension, which is carried to a chamber of about one-half cubic inch capacity at the base of the jet where it mingles with oxygen and is burned in the ordinary jet, and the flame projected against a piece of lime, as in the oxy-hydrogen light. In order to start the light it is necessary to first heat the generator with a spirit lamp, until vapor is produced, when the oxygen is turned on and the spirit lamp withdrawn. The inventor claims that the light thus produced is more brilliant and cheaper as well as more convenient, where it is difficult to obtain ordinary illuminating gas.

American Association for the Advancement of Science.—From the circular just issued by Professor Putnam, the permanent secretary, we learn that the twenty-fourth annual meeting of the American Association for the Advancement of Science will open at Detroit, on Wednesday morning, August 11th, 1875, at ten o'clock. Present appearances indicate one of the largest meetings the associa-

tion has ever held. As it is the first meeting under the new constitution, adopted at Hartford, it is believed that many of the evils noticeable in former meetings will be remedied, and that the efficiency of the association as a whole will be largely increased. It will be remembered that at the chemical centennial, held at Northumberland last year, a movement was made toward the formation of a chemical section in the American Association. At Hartford, the proposition was favorably received, and a permanent sub-section of Section A was formed, devoted to chemistry, chemical physics, chemical technology, mineralogy, and metallurgy. It is hoped that all who are interested in the above subjects, especially those who are engaged in the larger chemical and metallurgical industries, will be present at Detroit and make the new sub-section of chemistry a success. The officers of the sub-section are permanent officers, being elected at the meeting previous to the one at which they are to serve. Professor S. W. Johnson, of Yale College, is President, and Professor F. W. Clarke, of Cincinnati, is Secretary of the Chemical sub-section for the Detroit meeting. Beside this, a special gathering of Entomologists is expected, and the entomologists and archæologists intend to organize a section of anthropology. The local organization at Detroit is most complete, and it is clear that nothing will be wanted to make the meeting a noteworthy one socially, as it now promises to be intellectually.

The Flat-footed or Tee Rail.—The following letter addressed to the President of the Institute was read at the stated meeting, for June, and will prove of interest as it seems to establish beyond doubt the fact of Mr. Stevens being the original designer of the flat-footed, or, as it is more commonly known in this country, the Tee rail, and not Charles B. Vignoles, late President of the Institute of Civil Engineers of England, as is commonly believed in Europe.

Dear Sir:—I herewith send you two pieces of rail, one nickled, the other plain, just as cut from the rail. I present them to the Institute as specimens of what we may call an historical rail; they are cut from one of the first flat-footed rails ever rolled. This rail was designed in 1830, by Robert L. Stevens, of New Jersey, for the Camden and Amboy Railway, was rolled in 1831, and laid in 1832. Many of these rails I saw laid. I now bring this rail to your attention, chiefly to show that Mr. Stevens was the designer and origin-



FAC-SIMILE OF THE ORIGINAL DESIGN, BY MR. ROBERT L. STEVENS, OF THE FLAT-FOOTED RAIL, TAKEN FROM A CIRCULAR ADDRESSED TO MILL OWNERS IN ENGLAND, IN 1830.

ator of the first flat-footed rail, a rail now known throughout all Europe as the "Vignoles" rail. As the flat-footed rail has been adopted by every country in the world, but England, it is not out of place for us to give the credit to whom it undoubtedly belongs. This original Camden and Amboy rail is worthy of some attention on account of its superior quality, some of these rails having done service in the main tracks for about twenty years, and an additional service in side tracks for twenty years more.

* * * * * * * *

I was informed, some years since, by the local Supt. of the Camden and Amboy Railway, that the quality of iron in this rail is so good, that when they wished a hundred tons of good bar iron they took these rails from the track and had them rolled into bar iron.

Another point worthy of notice in the design of this rail of Mr. Stevens, and carried out in construction, is that it had the first approach to the "Fish-plate," now in general use. The ends of the rails had one bolt-hole in each end; the ends were connected by plates and bolts, and differed only from the fish-plates of the present day by having one bolt, instead of two, in each end of each rail. This end plate, or connecting link, is shown in the original design of Mr. Stevens, in the circular he addressed to the mill-owners, in England, in 1830, a photo-printed copy of which I send you. This original design shows it was intended to have a bulge, or widening of the lower flange every two feet, where it rested on a sleeper, but as there were mechanical difficulties in the way of rolling this rail, Mr. Stevens altered the design to the pattern of which I send you pieces.

* * * * * * * *

I am, Dear Sir, yours most sincerely,

W. W. Evans,

M. Am. Society Civil Engineers.
M. Inst. Civil Engineers.

We give also a copy of the letter of Mr. Frank Thompson, General Manager, Pennsylvania Railroad Company, accompanying a piece of the rail.

Pennsylvania Railroad Company.

Philadelphia, February 27, 1875.

Thomas C. Clarke, Esq.

Dear Sir:—I take pleasure in forwarding you one yard of the rail known as Mr. Stevens' pattern, laid in 1832 on the Camden and Amboy Railway. The following is a quotation from a letter from the Superintendent of the Amboy Division, indicating that the rail has really been in service for about 40 years.

"No record to enable us to tell when the piece of iron was taken from the main track. My recollection is that it was all replaced about 1852 or 1853. The piece sent you was probably on the main track for about twenty years, and in a siding for about twenty years more."

"Yours, Respectfully,

"FRANK THOMPSON, *General Manager.*"

The cuts given are fac-similes of the drawings in the circular sent to mill owners by Mr. Stevens in 1830.

Water Works and Drainage at Atlantic City.—The geological formation of the island on which Atlantic City is situated, does not furnish water suitable for cooking and drinking, and it has been necessary to use rain water stored in cisterns for these and other domestic purposes. This source of supply being both expensive and unreliable, and the want of an ample supply of water as protection against fire, has led the Camden and Atlantic Railroad Co. to take steps towards the erection of water works.

It is proposed to take the water from Absecom Creek, at the grist mill of A. Doughty, situated about 8 miles from Atlantic City, where there is a fall of 5 feet. At this point it is proposed to place two turbine wheels, each driving two piston pumps, forcing the water through a 16-inch main pipe, to a standpipe 14 feet in diameter, and 100 feet high, located at some convenient point in the town.

These pumps are to have a combined capacity of 500,000 gallons per day, under a head of 80 feet in the standpipe, which will be an ample supply for 9 months of the year. The two wheels will be so controlled by a governor, operated by the pressure in the main pipe, that both will run until the head reaches 80 feet, when one will stop and remain so as long as the other can maintain it at that point. The second wheel will continue to run until the head reaches 100 feet, when it also will stop—the wheels starting again as the head falls below the points named.

A larger supply being required during the summer and in case of fire, there will be located in the town, near the standpipe, a steam pumping engine, which shall take suction from the 16-inch main, and maintains a head of 100 feet in the standpipe, the water wheels running at the same time to overcome the friction in the eight miles of main pipe.

For fire service, the connection with the standpipe will be cut off,

and the water forced directly through the distributing main under a pressure of one hundred pounds per square inch, which will be sufficient to throw water over the highest buildings, by connecting the hose directly to the hydrants. The arrangement by which this change is made, and the governor controlling the action of the water wheels, are the inventions of Mr. H. P. M. Birkinbine, by whom the designs for the entire works are being prepared. The whole cost of the works, not including the real estate, is estimated at $180,000. The Railroad Co. asks the co-operation of the citizens and property owners, both for the raising of the funds and that they may have a voice in the management of the works, but we are informed that it will probably build the works even if the citizens do not take part in the enterprise.

Another much needed improvement is the main sewer proposed to be built, beginning at a point near where the road bridge crosses Beach-thoroughfare, thence through Florida, Atlantic, and Massachusetts Avenues to Clam Creek, a distance of 13,000 feet. The bottom of this main sewer is to be one foot below low tide, and to be five feet high in the clear. The distance between the ends of this sewer by the course it takes, being about three miles less than by the channel of the natural water course, it is believed that the ordinary flow will keep it clear, but to secure a more certain and rapid action, it is designed to construct gates or valves at either end of the sewer, to be closed when the tide is high and the sewer full of water, and opening them alternately when the tide is low. This system of flushing, we are told, has been in use for several years in Charleston, and has proved very satisfactory. The total cost of the main sewer is estimated at from seventy to ninety thousand dollars. The branch sewers to be paid for by the property immediately benefited.

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Paton and Harris' Pyroletor, for the Extinction of Fire on Board Ships.—Under the supervision of Dr. R. Carter Moffat, who conducted the experiments, a large party of gentlemen connected with shipping and the Board of Trade assembled at Greenhithe, near Gravesend, recently, to witness the power of the pyroletor to extinguish fire in closed places. The pyroletor consists of a small double pump worked by hand, which sucks up from tubes on either side of it strong muriatic acid and a solution of bicarbonate of soda, which

commingle in a generator forming part of the pump, and the carbonic acid gas and solution of salt pass at once down a metal pipe to the hold, along whose keelson runs a perforated wooden box which admits of the gas passing through to the burning material. The agent, therefore, for the extinction of fire is dry carbonic acid gas, which has no action on cargo. A well-appointed steamer conveyed the party from Blackwall to Greenhithe, where a large wooden barge had been prepared for the experiments. Its entire hold was covered to a depth of several feet with wood shavings, cotton-waste saturated with turpentine, and naphtha. A temporarily-raised and by no means air-tight wooden deck, with loosely-fitting boards, formed the wide hatchway covering. After the apparatus had been explained by Dr. Moffat, its action as a common wash-deck pump and fire-engine for fire above board had been observed, when it acted very efficiently, throwing water a distance of at least 30 feet, the pipes to the chemicals were attached, and the signal given to set fire to the inflammable materials in the hold. Immediately the flames ran along the entire cargo and issued above the temporary deck, which was then covered with boarding. The pyroletor having been brought into action, and although nearly half a gale of wind was blowing, the fire was completely extinguished in four minutes. The experiments were so completely successful, and the efficiency of the apparatus so apparent, that the party at once agreed to sign a memorial to ask Government to compel all long-passage ships conveying passengers and cargo to carry one of these instruments. It is computed that a 1200-ton ship requires about half-a-ton of each of the chemicals, which, with their packages, cost about £20.—*Chemical News.*

Franklin Institute.

HALL OF THE INSTITUTE, June 16th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock, P. M., Vice-President B. H. Moore in the chair.

The attendance was very large, the room being crowded to excess, and many members not able to gain admittance.

The minutes of the stated meeting for May were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their meeting held on the 9th inst., there were 12 persons elected members, and the following donations made to the library:

Report of the Superintendent of the United States Coast Survey, showing the Progress of the Survey during the year 1871. Washington, 1874. From C. P. Patterson, Supt. U. S. C. S.

Report of the Permanent Committee of the First International Meteorological Congress at Vienna, for the year 1874. From the Meteorological Committee. London.

Notes on Public Works in the United States and Canada, including a description of the St. Lawrence and Mississippi Rivers and their Main Tributaries. By Sir Charles A. Hartley, M. Inst. C.E. From the Author.

Bulletin of the United States Geological and Geographical Survey of the Territories. Bulletin No. 2. From the Department of the Interior. Washington.

Bulletin of the United States Geological and Geographical Survey of the Territories. Bulletin No. 3. From the Department of the Interior. Washington.

Ueber die Wasserabnahme in den Quellen, Flüssen und Steömen bei gleichzeitiger Steigerung der Hochwasser in den Culturlandern. Von Gustav Wex. Wein, 1873. From the Author.

Annales des Ponts et Chaussées, for May, 1875. From the Editor. Paris.

Annual Report of the Committee of Management of the Manchester Steam Users' Association, 1874. From the Association.

Annual Report of the Chief Engineer of the Water Department of the City of Philadelphia, for the year 1874. From Wm. H. McFadden, Chief Engineer.

Minutes of the Proceedings of the Institution of Civil Engineers, with other selected and abstracted papers. Vol. 39. By James Forrest. From the Society.

English Patent Specifications for 1873 and 1874, with an Index of Patents and Patentees for 1872. And the following Abridgements of Specifications:

Milking, Churning and Cheese-Making, A. D. 1777-1866. London, 1874.

Drains and Sewers; including the Manufacture of Drain Tiles and Pipes. A. D. 1619-1866. London, 1874.

Anchors, A. D. 1796-1866. London, 1874.

Mining, Quarrying, Tunneling and Well Sinking, A. D. 1688-1866. London, 1874.

Masts, Sails, Rigging, etc., including apparatus for raising and lowering ship's boats, A. D. 1625-1866. London, 1874.

Wearing Apparel, Division 1. Head Coverings, A. D. 1637-1866. London, 1874.

Metallic Pipes and Tubes, A. D. 1741-1866. London, 1874.

Electricity and Magnetism; their generation and applications. Part 2. A. D. 1858-1866. London, 1874.

Hydraulics, A. D. 1617-1866. London, 1874. From the Commissioner of Patents of Great Britain.

Index to the Commissioner of Patents Journal, for 1874. Index to Foreign Scientific Periodicals contained in the Free Public Library of the Patent Office. Indexes of Authors and Subjects for 1872. Chronological and Descriptive Index of Patents applied for, and Patents granted, in 1874. List of Specifications and other Publications issued weekly, for 1874. From the Commissioner of Patents. Great Britain.

Lecture on the late Improvements in Steam Navigation and the Arts of Naval Warfare, with a brief notice of Ericsson's Caloric Engine. By John O. Sargent. From Mary A. Cox. Philadelphia.

Observations on the best means of Propelling Ships. By Alexander S. Byrne. New York, 1841. From Mary A. Cox. Phila.

The Actuary also reported that in accordance with the recommendation of the Committee on Science and the Arts, the Board of Managers have awarded the Scott Legacy Medal and Premium to E. A. Goodes for his improvement in Sewing Machines.

The Secretary read a letter from W. S. Stokley, Mayor of the city, transmitting to the Board a certified copy of the following ordinance, approved June 5th, 1875.

"An ordinance to appoint a commission on supply of water of the City of Philadelphia:

"SEC. 1. The Select and Common Councils of the City of Philadelphia do ordain, That the Mayor be requested to appoint a Commission of five scientific and practical engineers, to be selected by

him from not less than eight names, which are to be recommended by the Board of Managers of the Franklin Institute, to whom, in connection with the Chief Engineer of the Water Department, shall be referred the entire subject of the present and future water supply of the City of Philadelphia, and to report their views to Councils.

"SEC. 2. That the sum of one thousand dollars be, and the same is hereby appropriated to pay the expenses of the above commission, and warrants shall be drawn by the Chief Engineer of the Water Department in conformity with existing ordinances."

The following communication to the Mayor, showing the action taken by the Board, was also read:

Franklin Institute, June 10th, 1875.

"To the Honorable W. S. Stokley, Mayor of Philadelphia:—

"Sir: I have the honor to transmit herewith the names of the eight engineers, recommended by the Board of Managers of the Franklin Institute, at a meeting held June 9th, 1875, in accordance with an ordinance to 'Appoint a commission on Supply of Water for the City of Philadelphia,' approved June 5th, 1875.

"The names are as follows:

FAIRMAN ROGERS,	JAMES E. SMITH,
WM. E. MORRIS,	SOLOMON W. ROBERTS,
W. MILNOR ROBERTS,	W. HASSEL WILSON,
FREDERICK GRAEF,	WM. J. MCALPINE.

Respectfully,

D. S. HOLMAN, *Actuary*.

The Secretary also read the following, from the minutes of the meeting of the Board, held on the 1st inst.

"The Treasurer reported that he had received to-day, from the executors of Asa Whitney, twelve shares of the stock of the Railway Equipment Trust of Pennsylvania, for one thousand dollars each, bearing eight per cent. per annum interest, and five hundred dollars in cash, making in all twelve thousand five hundred dollars, being in full for the legacy given to the Institute by the will of Mr. Whitney; and that the family of Mr. Whitney had paid the collateral inheritance tax on said legacy, amounting to six hundred and twenty-five dollars, whereby the Institute had received the whole amount of the benefaction, free of any charge.

"And, on motion of Mr. Fraley, it was

"*Resolved*, That the Secretary of the Institute be requested to present thanks to the family of Mr. Whitney for their liberal gift of the collateral inheritance tax on the legacy of Mr. Whitney, and to acknowledge the receipt of the bequest as reported by the Treasurer."

The Secretary stated that the printing of the Report of the late Exhibition had so far progressed that it will be ready for distribution in a few days.

The Secretary then presented his Report on Novelties in Science and the Mechanic Arts, which embraced a paper barrel, the invention of M. N. Keely; a new street car starter, the joint invention of Chas. J. Shain and Geo. L. Waite; a new method of canceling postage stamps, invented by John Shinn; a new mail bag fastener, by Geo. O. Clark; an automatic car brake, by Thos. E. Thompson; and a piece of flat-bottomed or Tee rail, from one of the first ever made, having been designed by Robt. L. Stevens in 1830, rolled in 1831, and laid on the Camden and Amboy Railroad in 1832, and had been in service 40 years.

The Secretary then described with the aid of diagrams and pictures on the screen, the fall of the bridge across the Big Black River, on the line of the railroad leading from Vicksburg to Jackson, Miss.*

The Secretary projected on the screen a number of views, showing the progress on the Centennial Buildings, and also described his improved method of illustrating the dissection or negative crystallization of ice.

Prof. Geo. F. Barker was then invited to describe his new Lecture Galvanometer, which he did, giving a number of illustrations of its delicacy and general adaptability to lecture purposes.

The new oxy-hydro-carbon light, invented by N. H. Edgerton, was described, and its illuminating power, as compared with the lime light, was shown by projecting pictures on the screen.

Prof. Barker then described and gave some illustrations of the power of the Gramme Magneto-Electric Machine, which was placed on the stage and driven by a Shapley steam engine; both of which will be found described in the JOURNAL for June, 1875.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

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* An account of this, by Wm. E. Morris, C.E., will be found elsewhere in this No. of the Journal.

The Challenger's Scientific Work in the West Pacific.—The following is a short account of the scientific work of the Challenger in the West Pacific Ocean:—

We established seven deep-sea observing stations between Mindanao and the Admiralty Islands, and at each of these we sounded, took samples of the bottom, took a series of temperatures at different depths, and got specimens of water from surface, the bottom, and intermediate depths, for the determination of the specific gravity and for chemical analysis. At five of the seven stations, the trawl was sent down and a fair representation of the deep-sea fauna was procured. The greatest depth on this line—2,500 fathoms—we found between the Molucca Passage and the Pellew Islands. The samples of bottom varied in character according to the depth, very much as in the Atlantic. The average temperature of the sea surface during this part of the cruise was 82·5 deg. Fahrenheit. The serial temperature soundings seem to show that a great part of the Western Pacific is not entirely in free communication with the Southern Sea, for the water, after sinking rapidly in temperature until it reaches 34 5 deg. Fahr., at a depth of 1,500 fathoms, maintains that temperature for all the greater depths. The section from the Philippines to the Admiralty Islands may be considered to have been taken, roughly, along the Equator, as it was all between lat. 5 deg N. and lat. 3 deg. 3 min. S. The section, 2,250 miles long, from the Admiralty Islands to Japan, was practically meridional. The observing stations in the second section were 12 in number, and pretty regularly distributed with regard to distance. The greatest depth was found on the 23rd of March in 4,575 fathoms. This is the deepest trustworthy sounding on record, with the exception of two taken by the Tuscarora, off the east coast of Japan, in 4,643 and 4,655 fathoms respectively, but no sample of the bottom was procured on either of these occasions. The sounding in 4,575 fathoms was taken in the morning. Only a very small sample of the bottom came up, and the depth was so unexpected that it was decided to repeat the sounding to avoid all possibility of error. In the meantime the ship had drifted a little, and the second sounding, which was most satisfactory in every respect, gave 4,475 fathoms. The tube of the sounding machine contained an excellent sample of the bottom, which was of a very peculiar character, consisting almost entirely of the siliceous shells of *Radiolaria*. Three out of four Miller-Casella thermometers sent down to these depths

were crushed to pieces by the enormous pressure they had to bear—between five and six tons on the square inch; the fourth withstood the pressure, and registered, when corrected for the pressure, at 1,500 fathoms, the usual temperature for that depth, 34·5 deg. Fahr., so that at that place there is a layer of water at that uniform temperature occupying the bottom of the ocean trough of the enormous thickness of 3,075 fathoms (18,450 feet). The soundings in this section were usually deep. They commenced near Admiralty Island, with a depth of 1,100 fathoms, and a characteristic globigerina ooze. The next sounding gives us "red clay" at 2,670 fathoms, and this is continued at like depths until we reach the western verge of the Carolines, where we have "gray ooze" at 2,325 fathoms and "globigerina ooze" at 1,850. Between the Carolines and the Ladrones there is the sounding in 4,575 fathoms, "red clay," with its character almost entirely masked by the quantity of siliceous shells. We then pass again into typical "red clay" which covers a vast plateau, almost level, at 2,400 fathoms, extending from lat. 15 deg. N. to Japan. The observations made in this section, taken in connection with others made elsewhere, would seem to point to the following law:—That "globigerina ooze"—a rapidly forming deposit, containing the whole of the abundant carbonate of lime of the shells of the foraminifera living on the surface and beneath it, and consequently consisting of almost pure carbonate of lime—generally occupies depths under 2,000 fathoms in the ocean; that beyond this depth, the proportion of the calcareous matter is gradually diminished, and the doposit, which now contains a considerable amount of clay, goes under the name of gray ooze; that at 2,600 fathoms the calcareous matter has almost entirely disappeared, and we have the purest form of "red clay," a silicate of alumina and iron with siliceous tests of animals; that from this point the "clay" decreases in proportion, and the siliceous shells increase, until at extreme depths the "clay" is represented by little more than a red cement, binding the shells together. As to the transition from the "globigerina ooze" to the "red clay," it is due to the removal of the lime of the globigerina shells by water and carbonic acid, or in some other way; the apparent disappearance of the "red clay" is a fallacy produced by the increased proportion of the siliceous shells. It has now been ascertained by the use of the tow-net at great depths that radiolarians and diatoms inhabit the water all the way down, and are probably

more abundant at greater depths, and it follows from this that four times more, at least, must die and shed their tests in 4,000 fathoms than in 1,000 fathoms.

The most marked temperature phenomenon observed in these two sections was the presence of a surface layer of water of an average depth of 80 fathoms, and a temperature above 77 deg. Fahr., extending northwards from the coast of New Guinea about 20 deg., and westward as far as the meridian of the Pellew Islands. The greater part of this huge mass of warm water is moving with more or less rapidity to the westward. The trawl was used seven times between New Guinea and Japan, but, owing to the great depth and the nature of the sea-bottom, the results were not large. Nearly every haul brought up, besides a few of the characteristic deep-sea creatures, lumps of water-logged pumice, many of them with small shells attached.—*English Mechanics' World of Science.*

Preservation of Plaster Casts.—Sir, The thorough saturation of plaster in melted paraffin will, I have reason to believe, preserve it from the weather in this country. An example so treated by me lay for some years on a marble block, in my garden here, in the open air, and remained uninjured. On the occasion, a good many years since, of a fancy fair for the benefit of the Female School of Art, connected with South Kensington, I contributed several specimens of small art works thus treated. This application of paraffin to plaster works of art was subsequently to this tried on a larger scale at South Kensington, without however any consultation with me, but from the want of proper treatment, it resulted in failure. The examples I have, and am ready to show, are apt to get rather too yellow, like yellow ivory, but my friend, Mr. G. F. Wilson, F.R.S., who obtained the paraffin for me in the first instance, tells me he thinks that if it were quite pure, it would retain its color.

The mode of saturation is no secret, as it is similar to that employed in the saturation of plaster casts in stearine. I am, etc.,

John Bell.

15 *Douro Place, Victoria-road, Kensington, W, June* 12, 1875.

P. S.—The paraffin hardens the plaster so much that the nail will scarcely scratch it. It increases its weight considerably, and gives it an appearance approaching transparency, like ivory, and preserves it in repeated washings.—*Journal of the Society of Arts.*

Centennial Exhibition.—The Art Gallery, of which we give illustrations, is a permanent building, the funds for its erection having been appropriated by the State of Pennsylvania and the City of Philadelphia, on condition that it shall remain as a memorial of the great exhibition. It is located on a line parallel with and northward of the Main Exhibition Building, on the most commanding portion of great Lansdowne Plateau and looks southward over the city. It is elevated on a terrace six feet above the general level of the plateau—the plateau itself being an eminence 116 feet above the surface of the Schuylkill River. The entire structure is in the modern renaissance. The materials are granite, glass and iron, no wood being used in the construction, the building is thoroughly fire-proof. It is 365 feet in length, 210 feet in width, and 59 feet in height, over a spacious basement 12 feet in height, surmounted by a dome.

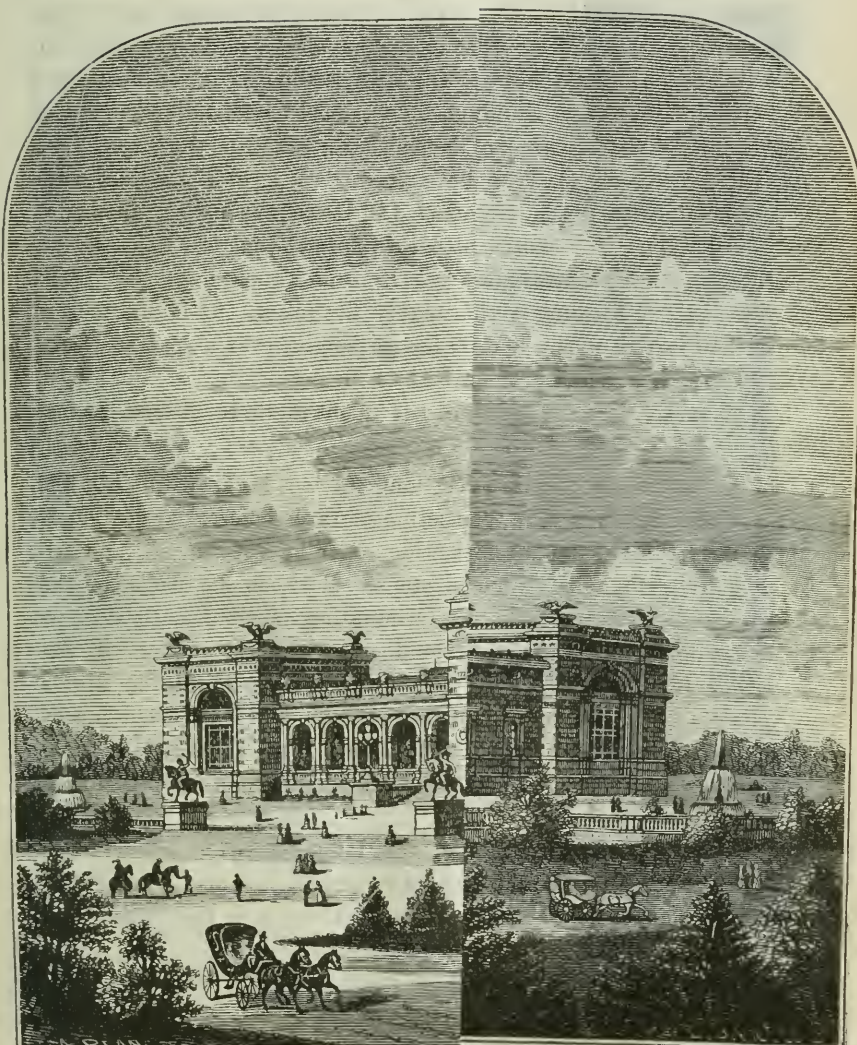
The main front looks southward; it displays three distinctive features:

1st. The central section, 95 feet long, 72 feet high, in which is the main entrance, 70 feet wide, consisting of three colossal arched doorways, 40 feet high and 15 feet wide, opening into a hall, and approached by a flight of thirteen steps. Between the arches of the doorways are clusters of columns terminating in emblematic designs illustrative of science and art. The doors, which are of iron, are relieved by bronze panels, having the coats-of-arms of all the States and Territories. In the centre of the main frieze is the United States coat-of-arms; the main cornice is surmounted by a balustrade with candelabras; and at either end is an allegorical figure representing science and art.

2d. A pavilion at each end, 45 feet long, 60 feet high, each displaying a window 30 feet high and 12 feet wide; it is also ornamented with tile work, wreaths of oak and laurel, 13 stars in the frieze, and a colossal eagle at each of its four corners.

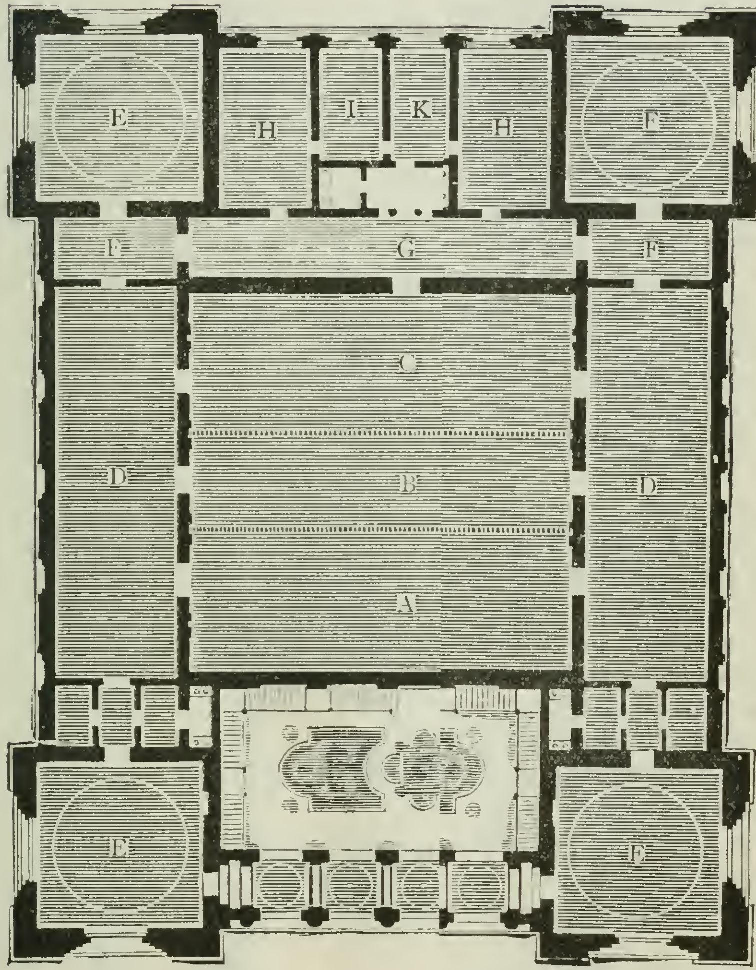
3d. Two arcades, each 90 feet long, 40 feet high, connecting the pavilions with the central section, and consist of five groined arches.

The arcades, a general feature in the old Roman villas but entirely novel here, are intended to screen the long walls of the gallery, and form promenades looking outward over the grounds and inward over open gardens, which extend back to the main wall of the building. These garden plats are each 90 feet long and 36 feet deep, ornamented in the centre with fountains, and designed for


A. BLANC

ART GALLERY.

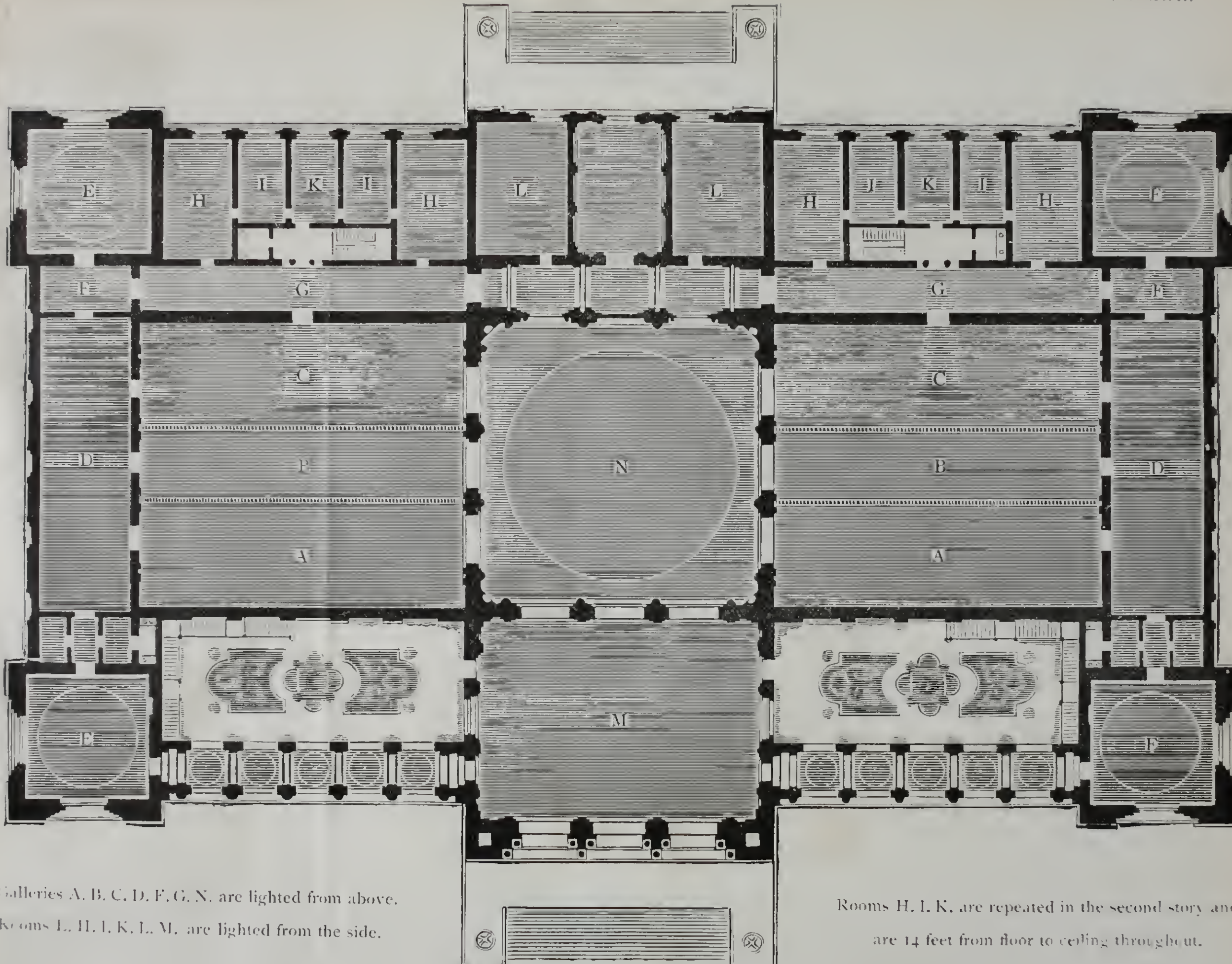
INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.



Galleries A. B. C. D. F. G. N. are lighted fr peated in the second story and

Rooms E. H. I. K. L. M. are lighted from t loor to ceiling throughout.

GF



Galleries A. B. C. D. F. G. N. are lighted from above.

Rooms L. H. I. K. L. M. are lighted from the side.

Rooms H. I. K. are repeated in the second story and are 14 feet from floor to ceiling throughout.

GROUND PLAN OF THE ART GALLERY.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.

the display of statuary. A stairway from the gardens reaches the upper line of these arcades, forming a second promenade 35 feet above the ground. Its balustrade is ornamented with vases, and is designed ultimately for statues. The cornices, the atticas, and the crestings throughout are highly ornamented. The walls of the east and west sides of the structure display the pavilions and the walls of the picture galleries, and are relieved by five niches designed for statues, the frieze is richly ornamented—above it the central dome shows to great advantage. The rear or north front is of the same general character as the main front, but in place of the arcade is a series of arched windows, twelve in number, with an entrance in the centre; in all, thirteen openings above, in an unbroken line, extending the entire length of the structure; between the pavilions is the grand balcony—a promenade 275 feet long and 45 feet wide, and elevated 40 feet above the ground, overlooking northward the whole panorama of the park grounds.

The dome rises from the centre of the structure to the height of 150 feet from the ground. By reference to the diagrams of the dome construction, it will be seen that the entire weight of the dome and the figure-bases at its corners, is carried by four main wrought iron truss girders, 85 feet 8 inches long, by 16 feet deep, resting on the masonry at their ends and 8 feet from the walls, laterally. Iron beams with one end in the masonry cross and rest upon the main girders and extend inward until their ends meet the circle of the interior finish, which is 56 feet in diameter. On these beams, immediately over the main trusses, rise the elliptical truss girders of the dome, the spaces between them being filled with glass. The dome terminates in an immense bell which supports a colossal figure of Columbia. Figures typifying the four quarters of the globe stand at the corners of the dome.

The main entrance opens on a hall, M, 82 feet long, 60 feet wide, and 53 feet high (see Ground Plan), decorated in the modern renaissance style; on the farther side of this hall, three doorways, each 16 feet wide and 25 feet high, open into the centre hall, N, 83 feet square, the ceiling of the dome rising over it 80 feet in height. From its east and west sides extend the galleries, each 98 feet long, 84 feet wide, and 35 feet in height. These galleries admit of temporary divisions, A, B, C, for the more advantageous display of paintings.

The centre hall and galleries form one grand hall, 287 feet long and 85 feet wide, capable of holding eight thousand persons, nearly twice the dimensions of the largest hall in the country. From the two galleries, doorways open into two smaller galleries, D, 28 feet wide and 89 feet long. These open north and south into private apartments which connect with the pavilion rooms, E, forming two side galleries 210 feet long. Along the whole length of the north side of the main galleries and central hall extends a corridor 14 feet wide, which opens on its north line into a series of private rooms, thirteen in number, H, I, K, L, designed for studios and smaller exhibition rooms. All the galleries and central hall are lighted from above: the pavilions and studios are lighted from the sides. The pavilions and central hall are designed especially for exhibitions of sculpture.

The work on this building is well advanced, the main walls being all up, except a portion of the west end, and the greater portion of the cornice set; the principal portion of the roof is on and all the frame work of the dome is in place, and there seems no reason why it should not be completed by the 1st of January, next.

The frame work of the eastern half of the Main Exhibition Building is up and nearly all under roof, and the erection of the western half progressing very well.

Of Machinery Hall all of the eastern end is under roof and the glass sides are in, and the whole being painted; the frame of the western half all up and a large portion of the roof is on.

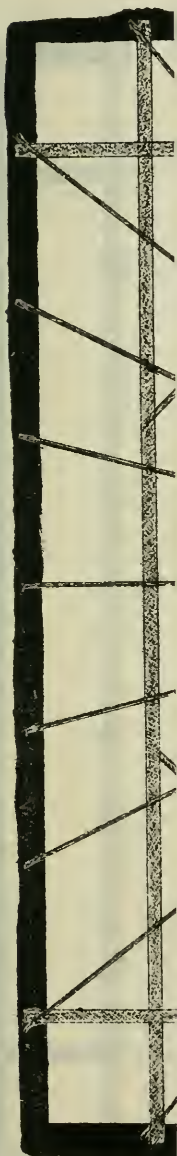
The iron and brick work of Horticultural Hall is up to the second story, and there is every prospect that it will be completed in the time specified in the contract.

One of the office buildings, at the intersection of Belmont and Elm Avenues, containing twenty-five office rooms, besides wash rooms, water closets, etc., is completed and now occupied.

The drainage, water supply, grading and other preparations, are all being pushed forward with such energy as carries conviction that all will be in readiness in due time.

The interest in the Exhibition is constantly increasing in all parts of our own country as well as abroad. Thirty-five of the States and Territories having formed official advisory boards, most of which are actively at work, and the following nations have accepted the invitation of the President.

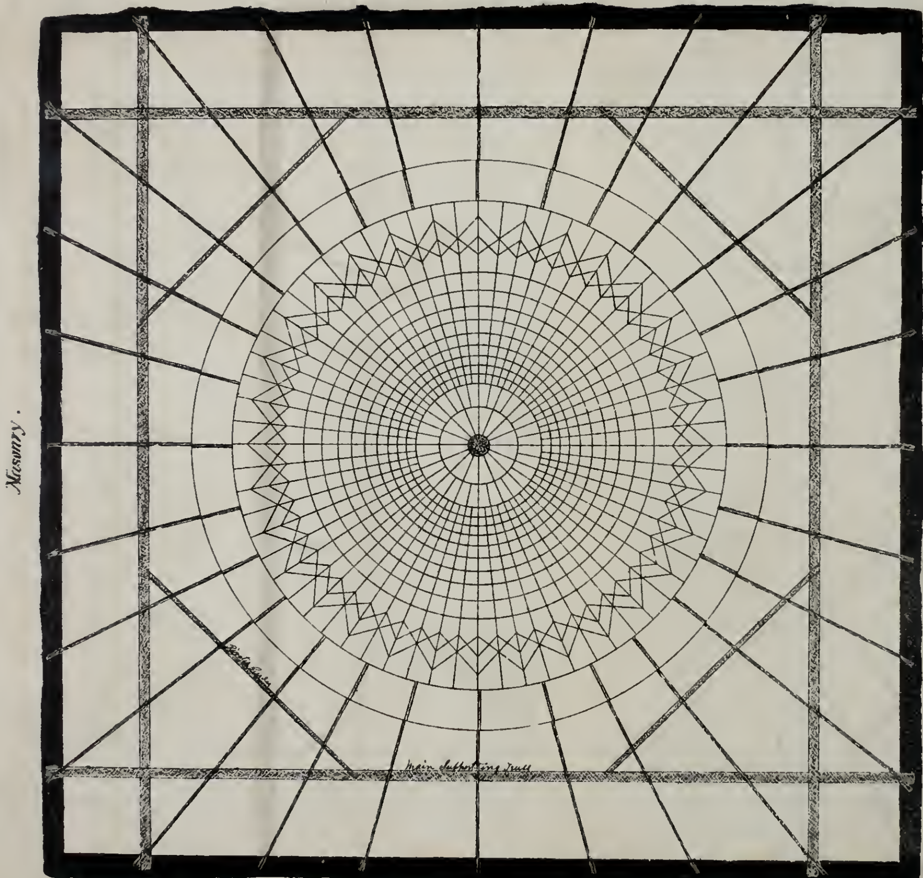
International Exhibitioı
Philadelphia. 1876.



International Exhibition.
Philadelphia. 1876

Art Gallery.
H. J. Schwarzmann, Architect

Diagrams of Dome Construction.



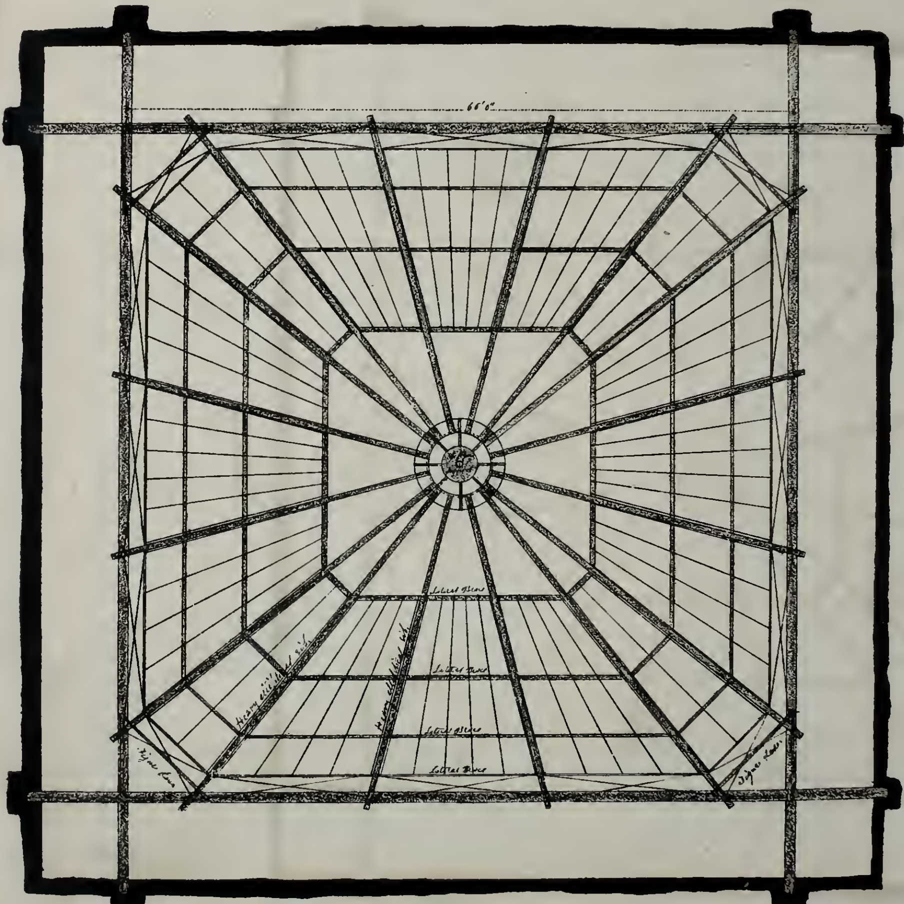
Plan of Internal Construction.

International Exhibition.
Philadelphia, 1876

International Exhibition.
Philadelphia, 1876

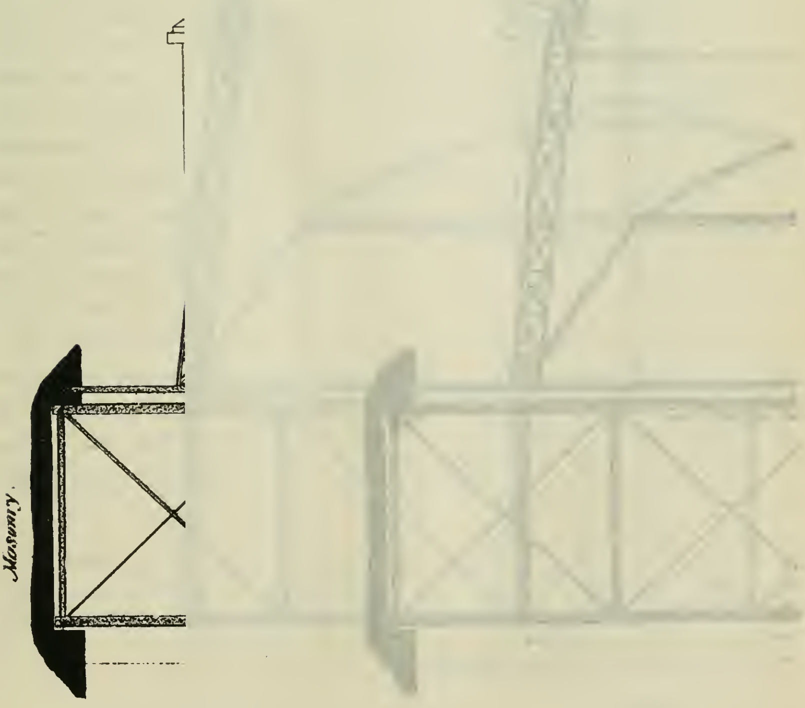
Art Gallery.

Diagrams of Dome Construction.

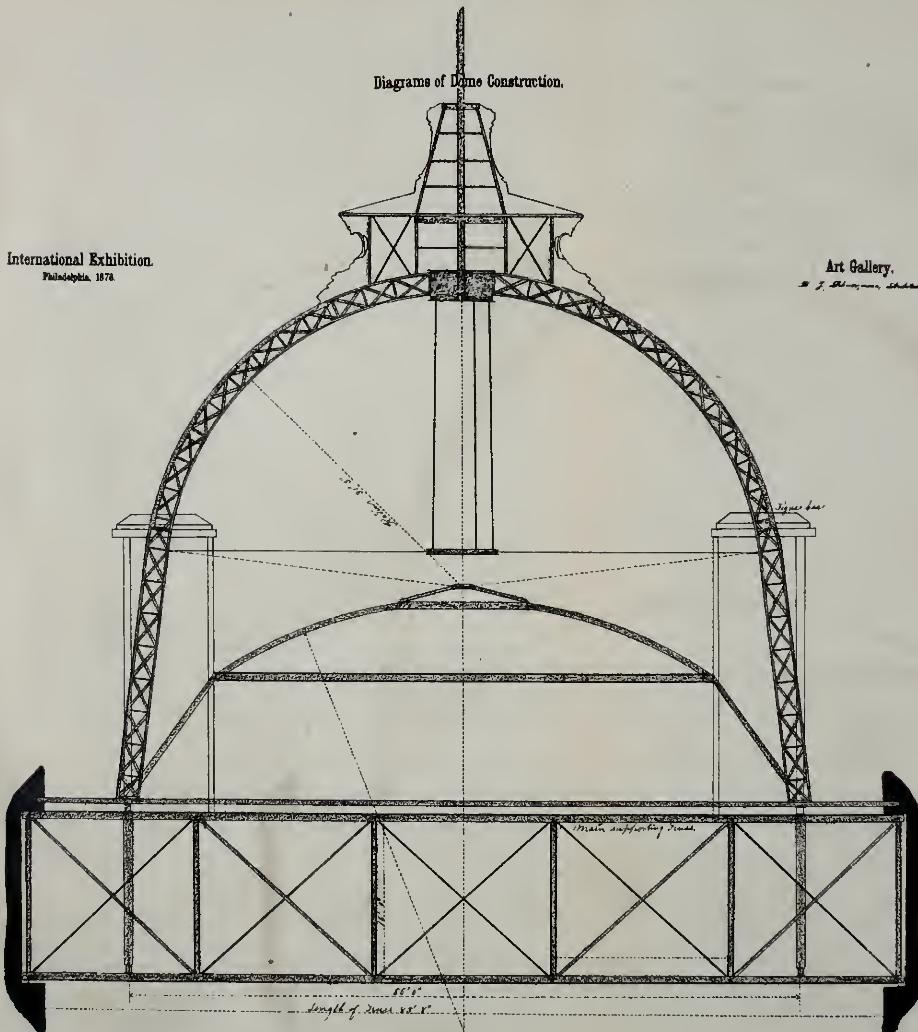


Plan of External Construction.

International Exhibi
Philadelphia, 1876.



Diagrams of Dome Construction.



Sections

Argentine Confederation, Austria, Australia, Belgium, Bolivia, Brazil, Canada, Chili, China, Denmark, Ecuador, Egypt, France, Germany, Great Britain, Guatemala, Hawaii, Hayti, Honduras, Holland, Japan, Liberia, Mexico, Netherlands, Nicaragua, Norway, Orange Free States, Persia, Peru, Portugal, Siam, Spain, Sweden, Switzerland, Tunis, Turkey, United States of Colombia, Venezuela.

A large portion of these have made liberal appropriations for the support of governmental commissions.

K.

Fracture of Feed Valve Boxes through the Rigidity of the Connections.*—Some cases of straining and fracture have recently been met with, in boilers under inspection, at the feed valve boxes, and to these defects it is thought desirable to call attention.

It is a convenient arrangement to fix the feed valve box directly to the front end plate of the boiler, and in many cases to bring up the feed pipe from below, and this, when sufficient play is given to the connections, is found to work well. But when the feed pipes are bound so tightly, either by the flooring plates or by the main feed pipe, as to be rendered rigid, a severe strain is put upon the feed valve box, and from this cause the fractures referred to above have arisen. Attachments to boilers should always be elastic, as all boilers move more or less from the varying temperature to which they are subjected which induces alternate expansion and contraction, while to this in some cases is added the effect of settlement. In a boiler recently examined in which the feed valve box had fractured, the boiler was found to have settled down about half an inch, and also to have thrust forward.

In addition to the strain induced by the movements of the boiler some pipes are strained in fixing. Too frequently, if the pipes are not set out with sufficient accuracy for the flanges to come well together, they are brought up by main force, and the strain thus induced cannot easily be detected by inspection after the work is put together.

* The practice of attaching feed pipes to the front head of cylindrical boilers is so common in the United States, that this extract from the report of the Chief Engineer of the Manchester Steam Users' Association for May and June, 1875, will be of interest.

In one range of boilers, the joint was found to spring open three-eighths of an inch on the bolts being withdrawn, showing how much force had been used in bringing the parts together, while, in another case, one of the feed valve boxes of a pair of new boilers broke through the root shortly after they had been set to work.

To prevent these fractures, it is recommended that the opening in the flooring plates through which the stand pipes pass, should be made large enough to afford ample room for play. Sometimes these pipes have been found so bound by the plates that as much as three-eighths of an inch has had to be cut away around them before they were fully relieved. In some arrangements a flange, cast upon the stand pipe as a base, rests on the floor plates and thus resists the movement of the pipe. In others, loose collars are introduced which cover the opening in the floor plates around the stand pipe, and make a neat finish, while at the same time they admit of free movement. The loose collar is much to be preferred and it is recommended that all those flanges that bear upon the flooring plates be chipped off.

Further, to prevent the stand pipe being bound fast by the main feed pipe, the connection between the two should be such as to admit of movement, and may be made by a wrought iron horse shoe shaped pipe or by a copper pipe either in the shape of a round elbow, or of a "swan neck," as may be applicable; while other arrangements for the same purpose will no doubt suggest themselves as required. The horse-shoe shaped pipe was introduced by the manager of a large mill, the boilers at which are under inspection, and has been found to give great satisfaction. When this elastic connection is introduced, the main feed pipe may safely be laid on the solid brickwork at the bottom of the pit beneath the flooring plates, but without this elastic connection, the plan of bedding the main feed pipe on the solid, throws a heavy strain upon the feed valve box when any downward movement of the boiler takes place.

It may be added that blocks are sometimes found wedged in beneath the blow-out elbow pipe, thus forming a solid abutment, which entirely frustrates the object of the recess in the front cross wall around this pipe, and, in the event of any settlement of the boiler, would inevitably induce a considerable strain.

The members are requested to instruct their mechanics to examine the connections to their boilers and where necessary, to have the

arrangements corrected in accordance with the recommendations given above.

It is very desirable that the inspectors should frequently examine the feed and blow out pipes in the hearth pit, and this they are prepared to do, but have sometimes hesitated to give the firemen the trouble of raising the flooring plates. The members will see, however, the importance of having these pipes examined, and it would assist in the accomplishment of this if they would be good enough to give their boiler attendants the necessary instructions.

L. E. FLETCHER,

Chief Engineer.

OFFICE—41 *Corporation Street, Manchester.*

The Phonometer. — One of the most fruitful sources of collision in navigation is foggy weather; a murky atmosphere is often the cause of far greater anxiety to the mariner than are reefs, icebergs, and many other dangers of the deep. The present system of fog signalling at sea removes those in command of ships but one degree from the utter state of helplessness in which its introduction found them. It consists simply in one ship announcing to another, by steam whistle, fog horn, or other means, that she is somewhere in her vicinity; but as to what her course is, nothing can possibly be known, so that each can only slacken her speed and steer in an imaginary right course, which has but too often proved a really wrong one. Nor are the perplexities of the position diminished, but sadly increased, by the unseen presence of a third or even a fourth vessel, and it will never be known how many ships have gone down with all hands during fogs. Survivors there are now and then to tell of these disasters, but they are few and far between, and it is not too much to assume that of our missing ships a very large number have been cut down in a fog. The anxious experiences of Captain R. E. Harris, during many dense fogs, led him to attempt the solution of the problem of comparative safety for vessels under such conditions. He knew that at night, in clear weather, his ship's course was made known to others, and the course of others to him by visible means, and it occurred to him that he might so improve the audible means he had at command for rendering the presence of his ship known in a fog as to make her course known also. This idea he has worked out to a practical end, embodying it in an

instrument to which he has given the name of the Phonometer. By means of this invention the officer in command of a steamer can make known in which quadrant of the compass he is steering, navigation being thus greatly facilitated, and the risk of accident reduced to a minimum, either in narrow waters or in the open sea. The apparatus consists of the mechanism of a clock placed in a horizontal position under a special dial. The seconds are arranged near the outer circumference of the dial, which is about 8 inches in diameter, while the hour and minute dial is about 2 inches in diameter, and is placed on the lower part where the seconds dial of a watch is usually sunk. There are four seconds' hands placed at right angles to each other and radiating from the centre of the main dial. Outside the seconds' circle are marked five black segments with intervals between them. One segment measures ten seconds in length and the other four five seconds each, with intervals of three seconds. Outside the glass which protects the dial and pivoted at its centre is a brass segment plate so arranged as to obscure those segments on the dial not required for immediate use, and thus to prevent error in signalling. Around the dial and outside it, is a flat ring of metal about 2 in. broad on which all the points of the compass are marked. The apparatus is placed on a stand with the upper part of the dial towards the head of the ship, the stand being fixed on the bridge just by the steam-whistle so that both are under the direct control of the officer in command. In using the phonometer the compass-ring, or dumb-card, as Captain Harris termed it, which is a very important feature of the instrument, is moved round until the true points on which the ship is sailing is in a line with the ship's head, all the true points of the horizon being thus indicated. These points being accurately known, it follows that all steamers in each other's vicinity, fitted with the phonometer, will have the true quadrants of the compass distinctly and concordantly represented. The steam-whistle or fog-horn is the important adjunct of the phonometer, and it is the duration of each whistle or blast and their number that indicates the course of a ship. The black segment covering ten seconds of space is a measure of ten seconds of time, the other segments indicating periods of different duration, and a whistle of ten seconds' duration indicates that a vessel is steering within the quadrant from N. to E. $\frac{1}{4}$ N. Assuming this to be the course of the vessel, the brass-covering segment would exclude all the other black segments, and the officer would wait until one of the four

seconds' hands entered that segment. He would start the whistle and hold it on during the time the hand traversed that segment. This operation must be repeated at intervals during the continuance of the fog. Another ship coming within sound would at once know the course of the first, and would indicate her tack in like manner. Following out Captain Harris's code, two blasts, each of five seconds duration, with an interval of three seconds, represents from E. to S. ¼ E. Three blasts of similar duration and intervals represent from S. to W. ¼ S., while four blasts of the same length and spaces indicates from W. to N. ¼ W. The special object of the four seconds' hands is to enable the operator to reply readily to the signals from other ships, which could not be done if the revolution of a single hand had to be waited for. By the peculiar construction of the dial the necessity of counting the seconds when signaling is entirely obviated. The apparatus having been designed by a sailor, and being based upon nautical data, commends itself at once to the nautical mind, presenting no new theory, but being engrafted on ordinary practice. An inspection of its working has led us to the conclusion that, subject to such slight codal modifications as practice might suggest, it presents the true solution of the problem of safe navigation in foggy weather.—*The Times.* (London.)

Notice.—By the Committee on Publication.—Prof. Geo. F. Barker having resigned the editorship of this Journal, the present number is issued by the committee on publication under some disadvantage.

Until the appointment of an editor the Journal will be issued by the committee under the superintendence of Mr. J. B. Knight, Secretary of the Institute, to whom all communications intended for the Journal should be addressed.

The interruption to regularity of issue, caused by the resignation of the former editor, the committee will endeavor to rectify, and after the August number, [which will be subject to some detention] they hope to present the JOURNAL with regularity to its readers.

The Committee ask from the members and friends of the Franklin Institute their cordial support to the JOURNAL. Contributions of original matter suitable for its pages will be received by Mr. Knight, for the committee.

Bibliographical Notices.

Notes in Building Construction. Part I. *Published by Rivingtons. London, Oxford and Cambridge.* 1875.—This work, of which the first part, or elementary course only, has yet appeared, and for sale by J. B. Lippincott & Co., has been arranged to meet the requirements of the syllabus of the science and art department of the committee of council on education at South Kensington, London, and is intended for the use of students preparing for examination in building construction. It is a work, however, that strongly commends itself to any one interested in this specialty, and especially to those about entering an architect's office to study the profession.

It treats of those matters of which he preliminarily knows very little—and finds the necessity of knowledge daily, to wit, the practical details of his business. The information is worked up in very readable shape, being collected in as condensed a form as practicable, very largely from first-class authorities, perhaps not accessible to the student, or at least difficult to cull from if attainable. The book is hardly as "American" in style as we could wish, some such matters as, for instance, roof details, the joints and connections, etc., not being always of the most improved modern designs or according to the best practice in this country. Some of the formulæ also are not the best, nor according to the latest authorities. Still, however, those who are in search of information on the subject treated will find the work of great use and containing very much that is important and valuable. We hope soon to see the second and third parts of the work.

W.

The Report of the Twenty-Seventh Exhibition, held by the Franklin Institute, is now published and ready for distribution among the members. It makes a volume of 284 pages, and is a full history of the Exhibition from its first inception; including a catalogue of Exhibitors and full reports of the Judges in the various classes. There is also a plan showing the arrangement of the aisles and passages. The Treasurer's statement of the total receipts and expenditures, shows a profit of $52,371.37.

While its financial success must be very gratifying to every member, it is but one of the benefits which have been derived from the Exhibition. The large accession of new members, there having been four hundred and forty-two,—an increase of three hundred and eighty-two over the previous year—and the renewed interest among the old members can scarcely be measured in money, and must prove of great and lasting benefit to the Institute.

Civil and Mechanical Engineering.

JONVAL TURBINES, AND PLUNGER AND BUCKET PUMPS.

By Emile Geyelin.

Dynamometrical tests made on a Jonval Turbine, working under high pressure; also, measurements of actual delivery of water from two sets of pumps propelled by said Turbine, constructed for the city of Manchester, N. H., by the Geyelin department of the firm of R. D. Wood & Co., Philadelphia.

GENERAL DESCRIPTION.

These works are located at the mouth of Lake Massabesic, and comprise a fall of water of forty-five feet, which is led to a pumping station, from whence the water, to the extent of five hundred cubic feet per minute, is forced into a reservoir through an ascending main, twenty inches in diameter and seven thousand feet in length. The actual lift does not exceed, in ordinary condition, sixty-two pounds to the square inch; but all parts are constructed to resist a pressure of two hundred pounds to the square inch, the pumping works being so constructed as to force the water directly into the distributing main when desired. These works, including dam, water ways, and general design at the pumping station, were planned and directed by J. T. Fanning, H. E.; the Turbines and machinery proper were placed by E. Geyelin.

DESCRIPTION OF TURBINES AND PUMPS.

Two Turbines of one hundred and twenty-eight horse-power, each thirty-four and a half inches in diameter, receive the water from a chamber placed at the bottom of the fall, on top of which chamber is a stand pipe, that is to receive the recoil in case of a sudden closing of valves. The motions of these Turbines are independent of each other, and can be transmitted to either of two sets of pumps, by means of shifting gears.

TESTS MADE AT THE MANCHESTER WATER WORKS, JUNE, 1875, TABLE NO. 1.—WHEEL TESTS.

Number of Experiment.	Temperature of Water.	Time of commencing Test.	Time of closing Test.	Duration of Test in seconds.	Total number of revolutions of wheel during Test.	Number of Revolutions of wheel per second.	Number of Revolutions of wheel per minute.	Weight on scale in pounds.	Effect in feet pounds per second.	Head of water on wheel in feet and decimals of a foot.	Height of back water.	Acting head of water on wheel in feet and decimals of a foot.	Height of *Waste* Water going over a weir 8 ft. wide from both wheels.	Height of water going over a weir 8 feet wide from 1 wheel.	Cubic feet of water discharged per second less total waste.	Effect of same in feet pounds per second.	Ratio of effect of wheel.	Cubic feet discharged per second less ½ of the waste.	Effect of same in feet pounds per second.	Ratio of effect of wheel.	Velocity of centre of bucket of wheel in feet per second.	Ratio of velocity of centre of bucket and theoretical velocity of water	Horse power of wheel by Test, if increased to 45 feet head.	Cubic feet of Water discharged in a second under 45 feet head.
	Degrees	June 23, 1875. H.M.S.	H.M.S.										Feet.	Feet.										
1	69	4 20 06	4 21 48	102	500	4·902	294·	250	61·275	44·04	1·85	42·19	·204	1·112	27·969	73,539	·8333	29·190	76·697	·7989	37·54	·7206	126·75	31·134
		June 21, 1875.																						
2	69	10 34 03	10 35 13	70	300	4·2857	258·6	280	59·999	44·29	1·85	42·44	·204	1·113	28·0097	74,035	·8104	29·2357	77·259	·7766	32·82	·6282	122·65	30·993
3	69	10 51 26	10 54 40	194	500	2·5773	154·6	400	51·546	44·29	1·78	42·51	·204	1·113	28·0097	74,157	·6897	29·2307	77·387	·6661	19·73	·3773	108·75	30·942
4	69	1 08 56	1 11 14	138	500	3·6232	217·39	330	59·7828	44·21	1·85	42·36	·204	1·110	27·8802	73,579	·8125	29·1101	76·798	·7784	27 75	·5515	122·60	30·924
5	69	1 17 49	1 19 50	121	500	4·1322	248·	300	61·983	44·21	1·83	42·38	·204	1·110	27·8802	73,613	·8420	29·1101	76 834	·8067	31·63	·6059	127·12	30·924
6	69	1 22 13	1 24 43	150	500	3 3333	200·	350	57·333	44·21	1·83	42·38	·204	1·110	27·8802	73.613	·7788	29·1101	76·834	·7462	25·52	·4889	117 58	30·924
7	69	1 24 51	1 27 09	138	500	3·6232	217·39	330	59·783	44·21	1·83	42·38	·204	1·110	27·8802	73,613	·8121	28·1101	76·834	·7781	27·24	·5314	122·61	30·924
8	99	1 55 17	1 56 59	102	500	4·9020	294·	250	61·275	44·21	1 83	42·38	·204	1·110	27·8802	63.613	·8324	29 1101	76·834	·7975	37·52	·7206	125·67	30 924
9	69	1 57 20	1 59 05	105	500	4·7619	285·71	260	61·905	44·21	1 83	42·38	·204	1·110	27·8802	73.613	·8409	29·1101	76 834	·8057	36·47	·6986	126·96	30 924
10	69	1 59 25	2 01 13	108	500	4·6296	277·8	270	62·499	44·21	1·83	42·38	·204	1·110	27·8802	73.613	·8490	29·1101	76·834	·8134	35·45	·6791	128·17	30 924
11	69	2 01 23	2 03 15	112	500	4·4643	267·3	280	62·500	44·21	1·83	42·38	·204	1·110	27·8802	73,613	·8490	29·1101	76·834	·8134	34·19	·6549	128·17	30·924

Friction Pulley = 42 inches Diameter, 10½ inches Face.

Weight = 1593 pounds, about equal to usual shaft and gear.

Weight of Brake = 1023 pounds, balanced off.

SAMUEL WEBBER.

TESTS MADE AT THE MANCHESTER WATER WORKS, JUNE, 1875, EFFECT OF PUMPS, TABLE NO. 2.—WATER DELIVERED AT RESERVOIR.

Number of Experiment.	Number of wheels used.	Experiment commenced.	Experiment ended.	Duration of experiment expressed in minutes.	Number of Revolutions of wheel per minute.	Number of strokes of pump per minute.	Actual head of water on wheel in feet.	Height of flow of water over a weir 8 feet wide.	Height of flow of water over a weir 8 feet wide, while one of the wheels was running.	Cubic feet of water discharged through wheel per minute, less ½ waste.	Effect of same expressed in feet pounds per minute	Height to which the water was pumped.	Height of flow over a weir 5 feet wide, stationed at delivery in reservoir.	Cubic feet delivered per second.	Number of gallons delivered in 24 hours.	Weight lifted, expressed in feet pounds.	Weight due friction in pipe.	Total effect expressed in feet pounds.	Ratio of effect to power used.	Velocity of water in main, in feet per second.	Water used, to water delivered in reservoir.
		H. Min.	H. Min.																		
		June 25,	June 26,																		
1	1	10 52	11 06	14	107·16	15	42.33	·203	1·1280	29·794	78,547	110·55	0·391	4·007	2,590,004	25,528	12,07	28735	·3658	1·8368	7·448
		June 26,																			
2	1	10 01	10 20	19	135·74	19	42·80	·203	1·1690	31·466	83,873	110·59	0·453	4·9845	3,221,573	34,303	23,12	36615	·4365	2·2847	6·313
3	2	10 49	11 03	14	178·60	25	42·38	·203	1·5740	50·536	133,380	110·62	0·502	6·8573	4,431,989	47,191	54,58	52649	·3947	3·1431	7·369
4	2	11 11	11 34	23	214·32	30	42·28	·203	1·6590	54·564	143,684	110·66	0·629	8·097	5,233,228	55,793	80,61	63784	·4439	3 7113	6·241
5	1	12 40	4 40	240	142·88	20	44·858	·203	out	31·466	87,960	110·58	0·475	5·3469	3,455,817	33,731	25,28	39259	·4466	2·4508	6·

Water used to lubricate steps = 10·8966 cubic feet per minute = 4890·34 gallons per hour.
Revolutions of wheel to 1 stroke of pump = 7·144.
Number of strokes of pump attained by 1 wheel = 20·66.

Water pumped by calculation = 648242 gallons.
Water pumped by weir and lubricator = 595,529·86 gallons.
Water pumped by measure reservoir = 508,336·65 gallons.
Water as shown by weir in reservoir = 575,969·50 gallons.

SAMUEL WEBBER.

The gears are bevel and spur (mortise) and so proportioned as to give twenty-eight strokes to the pumps a minute, while the Turbine makes two hundred and twenty revolutions per miunte. The pumps are four in number and are placed in a vertical position. Diameter of plunger, eleven and a quarter inches; length of stroke, forty inches. The receiving valves are in each of the four pumps of the kind known as "Double Beat Cornish" and are seven in number in each set. The air vessels, placed at the junction of two pumps, are supplied with air by means of automatic pumps.

DESCRIPTION OF THE TESTS.

Two tests were made and conducted by Samuel Webber, H. E., of Manchester, who used the dynamometer and water guage, that served in the experiments made at Lowell, by J. Francis. The table No. 1, gives the results under different velocities, varying from 294 to 217 revolutions per minute, wherein the percentage of useful effect, varied only from 0·7989 to 0·7781. As shown, the best results were obtained at velocities of 270 to 280 revolutions per minute, amounting to 0·8134.

The duty of the pumps is given in table No. 2, the results therein stated were obtained by the measurement of the depth of water flowing over a weir, put up at the reservoir; width of weir, sixty inches. From the data obtained, the actual duty of the pumps is at thirty strokes, equal to eighty-eight per cent. of the theoretical capacity of the pumps. When the length of the ascending main (7000 feet) is taken into consideration and a probable leakage, these results are fair, though with a short and tight main, the duty should not be less than ninety-four per cent.

Export of the manufactures of Iron from Philadelphia.—During the fiscal year ending June 30th, proximo, Philadelphia exported to foreign countries the following iron products, aggregating $1,001,387. Railroad bars, $9,977; car-wheels, $64,900; machinery, $767,560; nails, $15,030; other manufactures of iron, $143,920.

The total exports of the city during the same time were $28,588,019.

REVIEW OF NAVAL CONSTRUCTOR WILSON'S EXPERIMENT FOR ASCERTAINING THE CENTRE OF GRAVITY OF THE U. S. STEAMER "SHAWMUT."

By Chief Engineer B. F. ISHERWOOD, U. S. Navy.

Having occasion to consult the 58th volume of this JOURNAL, my eye was arrested on page 97 of the number for August, 1874, by an article headed *Experimental Determination of the Centre of Gravity of the United States Steamer "Shawmut" by T. D. Wilson, Naval Constructor, U. S. N.* As this steamer was one of a class of large screw gun-boats for which I designed the machinery in 1863, and whose elements and performance I obtained with the greatest exactness, I read the article with interest in the expectation of finding the subject properly handled, and my knowledge of the qualities of those fine vessels increased. Great, therefore, was my disappointment, when in place of a carefully executed experiment under proper conditions, and an accurately calculated result from correct data, I found mainly errors of fact, procedure and deduction. Now, inasmuch as sagacious experiments of this kind are of the highest value in furnishing science with its indispensable data, so fallacious ones, being correspondingly injurious, should have their faults promptly exposed to prevent the serious mistakes that would follow their acceptance; and, as I am known to possess the true data in this case, I am not willing to sanction, by my silence, the propagation of errors I am able to correct.

The experimental method of determining the position of the centre of gravity of a ship, was completely set forth by Bouguer, more than one hundred and twenty years ago, as is well known to all persons educated in this and kindred subjects. To the dead Bouguer, therefore, is due the credit of the investigation and not, as the reader is left to infer from the remarks of Mr. Wilson, to the living Mr. Barnaby, whose demonstration has been textually copied word for word. The method, in fact, is neither new nor unknown, nor is there any difficulty in its application.

For the proper understanding of an experiment of any kind, the scale on which it was tried must be known, or the size of the object experimented on, which in this case would be defined by the dimen-

sions of the "Shawmut." As Mr. Wilson—apparently unaware of this necessity—has not stated these dimensions, I now give them in supply of his omission.

Length on mean load-line from forward side of rabbet of stem to after side of sternpost, . .	179·5 feet.
Extreme breadth, ...	30·0 feet.
Mean load-line above the lower edge of the rabbet of the keel, ...	9·33 feet.
Lowest port-sill above the mean load line, . .	5·5 feet.
Displacement to the mean load-line, . .	29216 0 cu. ft.
Area of mean load-line, ...	4196 0 sq. ft.
Area of the greatest immersed transverse section,	240·4 sq. ft.
Centre of displacement before the middle of the length,	0·2 foot.
Centre of displacement below the mean load-line,	3·87 feet.
Latitudinal meta centre above the centre of displacement, ...	8·53 feet.
Ratio of displacement to circumscribing parallelopipedon,	0·5813.
Ratio of load-line to circumscribing parallelogram,	0·779
Ratio of greatest immersed transverse section to circumscribing parallelogram, ...	0·858
Area of the ten principal sails. (Courses, topsails, topgallant sails, jib and spanker.) . . .	9199 sq. ft.
Centre of effort of the sails before the middle of the length of the mean load-line, . . .	6·56 feet.
Centre of effort of the sails above the mean load-line,	45·92 feet.
Ratio of forward moment to after moment, .	1·00 to 0·75.

In December, 1866, the "Shawmut" having on board all she could stow, including one hundred and sixty tons of coal, one hundred and eighteen men, bread for forty days, other provisions for sixty days, and water in tanks for eight days, was officially reported as having a mean draught of water of 10 feet above the lower edge of the rabbet of the keel, at which draught her displacement of sea-water is 917·8 tons. Now Mr. Wilson states that during his experiment her draught of water was 11 feet forward and 13 feet 6 inches aft above the bottom of the keel, corresponding to a mean draught of 10 feet 7 inches above the lower edge of its rabbet. As his experiment was made at Washington, this draught was in fresh water, but even after correction for sea-water it is still about 4 and 6-10ths inches more than

the reported deep load draught of the vessel in 1866. The exact displacement of the vessel at 10 feet 7 inches mean draught above the lower edge of the rabbet of the keel, is 965·4 tons in fresh water instead of the 1010 84 tons stated by Mr. Wilson. Further, I find the centre of displacement or buoyancy at that draught of water is 4·42 feet below the mean load line. Also, the meta centre is 7·56 feet above the centre of displacement. These errors vitiate Mr. Wilson's calculations, but he seems to have made a still more serious one (supposing his data to be correct) in giving 199·32 as the product of the weights into the distances through which they were moved, whereas, if we take the only weights and distances he gives, a very different result follows, namely:—

The transfer of the 9 inch gun = 10437 pounds = 4 66 tons × 20·66 feet = ...	96·27
The transfer of the 11 inch gun = 24159 pounds = 10·78 tons × 7·00 feet = ...	75·49
The transfer of the 20 pounder gun = 3793 pounds = 1·69 tons × 3·665 feet = ...	6·20
	177·96

The moments are thus 177·96, and not 199·32 as given by Mr. Wilson. He does not show how he obtained this 199 32, but merely says the moments amount to that figure. Experiments to be satisfactory and reliable, must have every process clearly described, and all the data exhibited in such manner that each step can be followed and every quantity recalculated. Nothing should be offered on faith. Restating his calculations with corrections, we have

$$\frac{1\frac{1}{3}}{20} = \frac{1}{15} = 3^\circ\ 48'\ 51'' = \cdot 0666$$

$$G\,M = \frac{pc}{W \text{ tang } \theta} = \frac{177 \cdot 96}{965 \cdot 4 \times \cdot 0666} = \frac{177 \cdot 96}{64 \cdot 386} = 2 \cdot 765$$ for the distance in feet that the centre of gravity is below the meta centre, and the centre of gravity is consequently 4·80 feet above the centre of displacement which is the real result sought by the experiment, but which he neglects to give. In strictness, the calculations on the vessel should be made to the exact difference of her draughts of water forward and aft, and not from the mean draught.

Mr. Wilson refers to a trial made with the British sailing sloop-of-war "Scylla" for the purpose of determining the position of her centre of gravity. He does not state the result, but the trial and the necessary calculations were made in a very different manner from those of the "Shawmut," and gave, for the position of that centre, 0·42 foot below the load water-line; while, in the case of the steamer "Shawmut," it seems to be 0·38 foot above, provided the experiment had been made with more accuracy than the calculations based on it.

Apart from the errors of calculation, the conduct of the experiment was such as to allow of nothing more than a very rough approximation to the truth. Such a trial to be of any value must be made in a dock or basin where there is no current and during a perfect calm, the vessel being free from moorings and merely held by lines. She should also be inclined both ways and to varying inclinations, and the mean of the determinations taken. In the case of the "Shawmut," however, the vessel was anchored in a stream, and the wind is stated to have blown a little fresh, which must have caused some rolling, but no effort appears to have been made to measure it. The fact that the vessel was riding with an anchor down, must have seriously affected the result; while nothing is said of the current which in the narrow and crooked channel of the river must have had influence and may have combined with the wind to increase or diminish the inclination. And then, only one inclination was tried which is altogether insufficient. As the pivot-gun formed a large portion of the inclining weight, the distance of the centre of gravity of its slide and of its carriage should have been given separately, as well as that of the gun, for they are at very different distances from the pivot or axis of motion. This seems to have been neglected, as only the distance the gun was moved is mentioned.

The principle on which the centre of gravity of a vessel is experimentally ascertained, is so simple that an extended explanation is not necessary, as easily appears from the following:—

If D represents the displacement of a vessel, p the meta centric height, and a the height of the centre of gravity above the centre of displacement or centre of buoyancy; then, if the vessel be inclined through the small angle θ, the expression $D(p - a) \sin \theta$ is the measure of stability at that inclination, provided it be so small that p may be taken as the initial metacentric height without sensible error. If

this inclination produced by placing a weight, w, at a distance, d, from the vertical longitudinal plane, then we have the equality

$$D(p-a)\sin\theta = wd\cos\theta.$$

$$p-a=\frac{wd\cos\theta}{D\sin\theta}=\frac{wd\cos\theta}{D}\text{ or }\frac{wd}{D\text{ tang }\theta}$$

$$\text{whence, } a=p-\frac{wd}{D\text{ tang }\theta}$$

This is the usual and proper expression for the height of the centre of gravity above the centre of displacement.

In calculating the displacement of vessels, the United States' ton of 2240 pounds is used both in this country and in England. The 35 cubic feet used to represent a ton in the English books from which Mr. Wilson so extensively copies, shows this, and is adapted merely for simplicity of calculation, though not correct, as it makes the specific gravity of sea-water 1024, and thus gives a small error of immersion on the safe side. The French naval architects always assume the specific gravity of sea-water at 1026, which is nearer the truth. The French ton is 1000 kilograms, or 2204·737 pounds, which closely approximates the English ton.

Other errors could be noted, but enough have been pointed out to show the utter worthlessness of the experiment, which both in its method and in the calculations based on it exhibit a want of knowledge of the true principles governing such an investigation. The science of the Navy Department must have been rated very low for such a report to have been submitted to it.

The U. S. Commission on tests of Iron and Steel.—Committee F, "On the effects of temperature," requests information as to the behavior of rails and machinery exposed to the extremes of temperature in northern latitudes, when subject to wear or breakage. Information of any kind on the subject, such as specimens, photographs, results of analysis, statistics of railroads, statements of manufacturers, essays, etc., may be sent to the chairman, R. H. Thurston, Stevens' Institute, Hoboken, N. J.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxix, page 405.]

In the columns of the following table, among others, will be found the frictional resistance of the immersed external surface of the hull; its resistance in function of form, and the variations of the latter from the law of the proportionality of the resistance to the square of the speed from 5·0 to 8·5 geographical miles per hour, both inclusive.

From the table, it will be seen that the variation of the resistance of the hull in function of form alone, is irregular, and very great from the law of its proportionality to the squares of the speeds, alternately decreasing and increasing. That variation is shown numerically in the last column of the table, in per centum of what the resistance would have been according to the above law; the prefixes of minus and plus indicate that the variation is below or above the law.

From the speed of 5·0 geographical miles per hour, the resistance increased in a less ratio than the law of the squares, up to the speed of 5·6 geographical miles per hour where the difference was 12 50 per centum less than what the law of the squares required. From the speed of 5·6 geographical miles per hour, the variation from the law slowly decreased until, at the speed of nearly 6·1 geographical miles per hour, the resistance was in accord with the law. From the latter speed, the resistance rapidly increased above that due to the law up to the speed of 7·8 geographical miles per hour, where it was 77·04 per centum greater than was due to the law. From the speed of 7·8 geographical miles per hour, the variation from the law decreased until, at the speed of 8·5 geographical miles per hour, the resistance was 62 per centum greater than was due to the law.

The resistance of the vessel at the different speeds was not only affected by the speed, but also, and greatly, by the action of the screw,

Speeds of the vessel, in geographical miles per hour.	Squares of the speeds of the vessel, proportionally.	Resistances of the vessel at the different speeds.				
		Resistance of the vessel, in pounds.	Frictional resistance of the external immersed surface of the hull, in pounds.	Resistances of the vessel in function of form alone.		
				In pounds.	Proportionally.	Per centum of the resistance of the hull in function of form due to the law of its proportionality to the sq. of the speed, which the experimental resistance varied from that law.
5·0	1·0000	315·4	220·1	95·3	1 0000	....
5·1	1·0404	323·3	229·0	94·3	0·9895	— 4·89
5·2	1·0816	333·2	238·1	95 1	0·9979	— 7·74
5·3	1·1236	344·1	247·3	96·8	1·0158	— 9·59
5·4	1·1664	356·0	256·8	99·2	1·0409	—10·76
5·5	1·2100	368·8	266·4	102·4	1·0745	—11·20
5·6	1·2544	380·7	276·1	104·6	1 0976	—12·50
5·7	1·2996	397·5	286·1	111·4	1·1689	—10·05
5·8	1·3456	414·3	296·2	118·1	1·2392	— 7·91
5·9	1·3924	431·1	306·5	124·6	1·3074	— 6·10
6·0	1·4400	449·9	317·0	132·9	1·3945	— 3.16
6·1	1·4884	470·7	327·7	143·0	1 5005	+ 0·81
6·2	1·5376	490·4	338·5	151·9	1 5939	+ 3·66
6·3	1·5876	513·2	349 5	163·7	1·7177	+ 8 19
6·4	1·6384	536·9	360·7	176·2	1·8489	+12·85
6·5	1·6900	560·6	372·0	188·6	1·9790	+17·10
6·6	1·7424	587·3	383·6	203·7	2·1375	+22·68
6·7	1·7956	616 0	395·3	220·7	2·3158	+28 97
6·8	1·8496	644·7	407·2	237·5	2·4921	+34·74
6·9	1·9044	676·3	419·2	257·1	2·6978	+41·66
7·0	1·9600	707·0	431·5	275·5	2·8909	+47·50
7·1	2·0164	739·6	443·9	295·7	3·1028	+53·88
7·2	2·0736	773·2	456·5	316·7	3·3232	+60·26
7·3	2·1316	805·8	469·2	336·6	3·5320	+65·69
7·4	2·1904	836·5	482·2	354·3	3·7177	+69·73
7·5	2·2500	867·1	495·3	371·8	3·9014	+73·40
7·6	2·3104	895·8	508·6	387·2	4·0630	+75·86
7·7	2·3716	920·5	522·1	398·4	4·1805	+76·27
7·8	2·4336	946·3	535·7	410·6	4·3085	+77·04
7·9	2·4964	967·0	549·5	417·5	4 3809	+75·49
8·0	2·5600	990·8	563·5	427·3	4 4837	+75·14
8·1	2 6244	1009·5	577·7	431·8	4·5310	+72·65
8·2	2·6896	1027·3	592·1	435·2	4 5666	+66·07
8·3	2·7556	1043·2	606·6	436·6	4·5813	+66·26
8·4	2·8224	1057·0	621·3	435·7	4·5719	+61·99
8·5	2·8900	1082·4	636·2	446·2	4·6820	+62·01

the slip of which operated to excavate the water at the stern; and, as the slip of the screw in per centum of its axial velocity increased with the speed of the vessel, this cause was aggravated in producing at the higher speeds the great variation of the resistance of the hull above the law of its proportionality to the squares of the speeds.

Of the influence of the number of blades into which the same area of the same kind of screw-surface is divided, and of their position.—Screws A, E, and F have exactly the same diameter, pitch, and surface; their only variation being in the number of blades into which that surface is divided. Screw A has two blades, one directly opposite the other. Screw E has four blades, arranged in pairs; the blades of each pair are directly opposite each other, and each pair is at right angles to the other. Screw F is a Mangin screw, sometimes called a duplex screw. It is composed of the two pairs of blades of screw E, with one pair placed directly behind the other, so that when viewed in projection on a plane at right angles to the axis of the screw, they appear as only one pair. This was effected by revolving the after pair of blades upon the shaft, until it came in exact projection with the forward pair.

The propelling efficiency of these three screws is exactly the same. They all give an identical slip for the same speed of vessel; and, as their surface is the same in area and in kind, and as they make equal revolutions for equal speeds, the power absorbed by their surface in overcoming the cohesive resistance of the water must be equal.

From these results the inference is warranted that, *in the case of screws having the same kind and quantity of surface, their propelling efficiency, in smooth water, is not affected by either the number or the position of their blades.*

The above equality of effect is limited strictly to the case of *smooth water*, because, in rough water, the superiority in propelling efficiency of the four-bladed over the two-bladed screw, both having the same kind and quantity of surface, is well established. This superiority results wholly from the pitching of the vessel in rough water, whereby, during a given portion of the time, a greater portion of the two-bladed screw is raised out of the water than of the four-bladed screw.

Were the entire pitch used, that is to say, did the screw-surface fill its entire disk when projected on a plane at right angles to its axis, the equality of effect of screws of different numbers of blades, but otherwise the same, would be equal both in smooth and in rough

water; but when only a small fraction of the pitch (from $\frac{1}{4}$ to $\frac{1}{3}$ as in the case in practice) is used, this equality no longer obtains, and the fewer the number of blades into which the surface is distributed, the less becomes the propelling efficiency in rough water. For illustration, take the extreme case of a screw having only one blade, and using only, say, one-fourth of the pitch, a moderate degree of pitching by the vessel would keep the whole of this surface out of the water during one-half of the time; if, however, the same quantity and kind of surface were distributed in two blades placed opposite each other, only one-half of the surface could be kept out of the water one-half of the time, and with four equidistant blades, a still less portion of the surface would be thus inoperative.

In the following table will be found the slips of screws A, E, and F, for the speeds of vessel from 5·0 geographical miles per hour to 8·5, increasing by one-tenth of a geographical mile per hour. These slips are taken from the curve obtained in the manner hereinbefore described, and they are expressed in per centum of the axial speed of the screw:

Speed of the vessel in geographical miles per hour.	Slip of the screw in per centum of its speed.	Speed of the vessel in geographical miles per hour.	Slip of the screw in per centum of its speed.	Speed of the vessel in geographical miles per hour.	Slip of the screw in per centum of its speed.	Speed of the vessel in geographical miles per hour.	Slip of the screw in per centum of its speed.
5·0	7·82	5·9	8·79	6·8	9·76	7·7	12·28
5·1	7·92	6·0	8·87	6·9	9·93	7·8	12·63
5·2	8·03	6·1	8·96	7·0	10·10	7·9	12·95
5·3	8·15	6·2	9·08	7·1	10·33	8·0	13 33
5·4	8·26	6·3	9·19	7·2	10·60	8·1	13·65
5·5	8·37	6·4	9 30	7·3	10·88	8·2	13·91
5·6	8·49	6·5	9·40	7·4	11·20	8·3	14·16
5·7	8·59	6·6	9·50	7·5	11·56	8·4	14·38
5·8	8·69	6·7	9·62	7·6	11·92	8·5	14·57

Had the resistances of the vessel at different speeds been in the ratio of the squares of those speeds, and had the water acted on by the screw continued in the same condition at those different speeds, then the slip of the screw would have been constant, retaining the same per centum of its axial speed at all speeds of vessel. But, as the vessel's resistance at different speeds varied from the law of the square of the speed and as the water on which the screw acted did not continue in the same condition at different speeds of vessel,

not filling the watery furrow made by the passage of the vessel, as rapidly at the higher speeds as at the lower, the screw's slip will vary accordingly to the value of those two causes.

Of the slips of screws of the same kind of surface, but of different quantities of surface.—Screw B, C, and D have the same diameter, pitch, number and form of blades as screw A, differing from it only in quantity of surface. The helicoidal surface of screw A is 6·1321 square feet; of screw B, 4·8078 square feet; of screw C, 3·0661 square feet; and of screw D, 1·7417 square feet. An examination of their slips for equal speeds of vessels, relatively to their surfaces, will detect the law which determines their slips in function of their surfaces. This examination having been made for the experimental slips of each of the above screws, taken from its separate curve of slips, as hereinbefore described, for each speed of vessel from 5·0 geographical miles per hour to 8·5, increasing by one-tenth of a geographical mile per hour, there results the following law: *The absolute slips of screws having the same kind of surface and differing only in its quantity, are for the same speed of the same vessel in the ratio of the square roots of their surfaces.* By absolute slip is meant the speed of the water-current, in geographical miles per hour, (not in per centum.) caused by the screw in the exactly opposite direction to the vessel's course, and due to the mobility of the water in furnishing a fulcrum for the action of the screw.

The *rationale* of the above law is—

1st. That the resistance of water to motion is as the square of the impressed velocity.

2d. That the resistance of the water to the advance of the vessel is equilibrated by the resistance of the water to the thrust of the screw.

3d. That, let the surface of the screw be what it may, the resistance of the water equilibrating its thrust is equal.

4th. That, the water, being a liquid, yields by virtue of its mobility to the thrust of the screw, and that the velocity or absolute slip, thus imparted to the water by the thrust of the screw, will be such that the product of the square of this velocity of the water and of the surface of the screw will be constant for a given speed of vessel.

Now, if $S =$ the surface of the screw, and $V =$ the velocity of the water, or absolute slip of the screw, for any given speed of the vessel, then $S \times V^2$ will be a constant for that speed of vessel; and if the

value of S be changed, then, to maintain the constancy of the product $S \times V^2$, the value of V must be changed in the inverse ratio of the square roots of S in the two cases.

For example: Let $S = 25$ square feet, and $V = 2$ geographical miles per hour with any given speed of vessel: then, $25 \times 2^2 = 100$ = the constant. Now, if S be reduced to 9 square feet, then to find the value of V in the new case, the speed of the vessel remaining as before, we have $\sqrt{9} : \sqrt{25} :: 2 : 3\frac{1}{2}$ geographical miles per hour, which is the velocity of the water pressed by the new screw surface 9 square feet, to give the vessel the same speed as before, because $3\frac{1}{3}^2 \times 9 = 100$ = the constant.

When the speed of the vessel and the absolute slip of the screw are know in geographical miles per hour, the relative slip of the screw, that is to say, its slip proportionally to its axial speed, is easily obtained and is usually expressed in per centum of the latter. For example, suppose in the first of the above cases that the speed of the vessel was 8 geographical miles per hour and the absolute slip of the screw 2 geographical miles per hour, then the axial speed of the screw would be $(8 + 2 =)$ 10 geographical miles per hour, of which 2 geographical miles per hour is 20 per centum, and this would be the slip of the screw. Now, in the second of the above cases, when the surface of the screw was reduced, but the speed of the vessel remained constant, the absolute slip of the screw being $3\frac{1}{3}$ geographical miles per hour, and the vessel's speed being 8 geographical miles per hour as before, the axial speed of the screw becomes $(8 + 3\frac{1}{3} =)$ $11\frac{1}{3}$ geographical miles per hour, and the slip of the screw becomes 29·41 per centum of its axial speed. By its axial speed is meant the product of its pitch and the number of revolutions made by it in a given time. This product is equal to the sum of the vessel's speed and that of the absolute slip of the screw.

When the speed of the vessel is given in geographical miles per hour, and the slip of the screw is given in per centum of the unknown axial speed of the screw, the slip of the screw in geographical miles per hour can be obtained from the following considerations:

Assuming the unknown axial speed of the screw to be represented by 100, its slip being known proportionally to this number, or in per centum of the screw's speed, the vessel's speed will be represented relatively to that of the slip by the difference between these two quantities, so that we thus have the speed of the slip and the speed of the vessel expressed proportionally; whence, as the absolute

speed of the vessel per hour in geographical miles is given, the absolute speed of the slip of the screw in geographical miles per hour will be obtained by the simple proportion, as the vessel's speed in per centum of the screw's speed, is to the screw's slip in per centum of the screw's speed, so is the vessel's absolute speed in geographical miles per hour, to the screw's absolute slip in geographical miles per hour.

For example, suppose the known slip of the screw to be 20 per centum of the screw's unknown axial speed, and the known speed of the vessel to be 8 geographical miles per hour, then the speed of the vessel relatively to the unknown speed of the screw will be (100 — 20 =) 80, and the proportion for obtaining the absolute slip of the screw in geographical miles per hour will be 80 : 20 : : 8 : 2, the screw's slip in geographical miles per hour.

The surface of the screw may be the helicoidal surface, or its projection on a plane at right angles to or parallel with the axis, or it may be expressed by the fraction used of the pitch. Any of these quantities may be used, so long as the same ones are continued throughout, the screw-blade having, of course, the same form or outline in all cases. That is to say, if its front and back edges are parallel and at right angles in one case, they are to remain so for the other cases.

Of the influence on the slip of the screw due to curving the front and back edges of its blades to the Griffith form, and to substituting a globe for the central portion of the screw-surface.—Screw H was made from screw G by cutting the forward and after edges of the latter to the Griffith form, and by bolting upon the hub between the blades pieces of wood accurately fitted to those spaces, forming a globe around the screw's axis of 1·25 feet diameter, equal to 28·85 per centum of the screw's diameter. The diameter of the hub of screw H was 11·54 per centum of the screw's diameter. As screw G had a pitch continuously expanding from the forward edge of its blades to the after edge, the result of cutting off surface at those edges was to slightly increase the initial and lessen the final pitch for screw H, leaving the mean pitch unchanged, and, consequently, the same in both screws H and G. The change of pitch thus made was not material in its effect upon the slip. The reduction of surface, however, was considerable, both at the centre and at the periphery of the screw, and its effect was to greatly increase the slip, raising it from 18·48 per centum, when the vessel's speed was 8·5 geographical miles an hour, to 21·99 per centum, of the screw's axial speed.

(To be continued.)

DESTRUCTION OF THE RAILROAD BRIDGE OVER THE BIG BLACK RIVER

By Wm. E. Morris, Civil Engineer.

About the year 1839 there was erected upon the Railroad between Vicksburg and Jackson, Mississippi, a high bridge across the Big Black River.

It was destroyed during the recent war and rebuilt in 1865 and '66. There were three spans, respectively 105, 140 and 165 feet in length, supported upon three high piers and one small abutment pier.

The two middle piers stood in the bed of the river, the eastern one upon a low flat of land not many feet above surface of low water, while the western one, serving as an abutment, was built upon a steep clay bank that formed the western shore of the river.

The abutment was built of brick, about 10 feet in height, while the middle piers had a height of about 80 feet, the lower 25 feet constructed of granite and the upper 55 feet of brick masonry.

Upon the eastern side the approach to the bridge was upon a high trestle work.

The bridge was rebuilt upon the "Fink Plan," with wooden chords, wrought iron suspension rods and cast iron bearing columns, with the road-way carried upon the chords. This was the most important and expensive structure upon the road, and its stability and permanence was justly considered by the officers of the company, of great moment.

After the annual meeting of the company, on the first Monday of May, 1874, the president, several of the directors, the superintendent of the road and myself, visited the bridge and found it in good condition, though the water of the river was quite high, some 25 feet above low water.

Ten days afterwards, the west bank of the river, both below the west abutment and in its rear, began to crack and slide slowly into the river. This continued until the abutment slid out of its position obliquely down the bank, throwing upon the sloping bank below, the western span of the bridge.

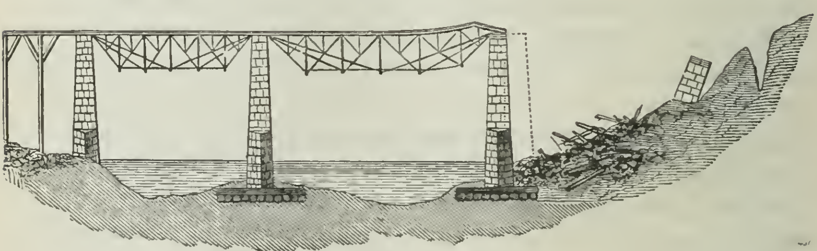
Two days afterwards the western pier was noticed to be moving bodily eastward, latterally. This it continued to do for several days,

until it had moved six feet, when the second span was thrown down. This movement of the pier brought the top of the masonry against the suspension rods of the bridge, pressing them upwards and carrying with them the first bearing columns and breaking the cords immediately over their top, which precipitated the second span into the river.

The pier kept its vertical position perfectly, and apparently did not sink. By an examination recently made, a year after the catastrophe, the pier is found to have moved about one foot farther, and still keeps its vertical position and its apparent altitude.

This pier, as before stated, was built more than thirty years ago, and during all that time had stood permanently, and safely carried its load. By the estimate of the resident engineer of the road, the pier contains about 2,500 tons of masonry.

It is understood to have been built upon two courses of heavy timber, laid crosswise.



Upon examination along the western shore of the stream, the cracking of the bank, and its sliding into the river was found to have extended some two or three hundred feet, both above and below the site of the bridge.

The immediate cause of the sliding of the bank was no doubt its thorough saturation with water from rains, and the high floods of the river; but this has almost annually been the case heretofore, and frequently the rains were heavier and the floods higher. It is evident that the material upon which the moved pier rested was moved in a body by the pressure of the sliding bank of the river.

This sliding mass did not accumulate and press against the side of the pier.

The above cut will serve farther to explain this remarkable occurrence.

Chemistry, Physics, Technology, etc.

REPORT ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By DR. A. W. HOFMANN.†

The Elements of Water.‡ By DR. A. OPPENHEIM.

Oxygen.—Like the evolution of human life, the development of every chemical art is connected with oxygen; Directly or indirectly, it intervenes in every manufacturing operation. With equal necessity, life and technology derive it from that exhaustless source of all being, the atmosphere. Furthermore, no discovery has had a greater significance for the history of culture than that of the material nature of the air, and the discovery—the centenary of which we commemorate this year—of its most important constituent, oxygen gas.|| To the same discoveries chemical industry owes its rational foundation and the possibility of its advancement, and thus both the existence and the progress of technology are linked to the same element. What, in comparison with these incalculable benefits, are the advantages which pure oxygen gas has conferred upon industry by its direct application? To give a reply to this question is the object of the following lines, and as no reports or text-books have hitherto treated this subject in a connected manner, we may venture to exceed in point of time the boundaries of this report.

Lavoisier, who first recognized in its full extent the importance of oxygen, took the first successful step in its technical application.

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† From the *Chemical News.*

‡ "Die Elemente des Wassers."

|| "On the 1st of August, 1774, I endeavored to extract air from mercurius præ cipitatus per se."—Joseph Priestley, "Experiments and Observations on Air," ii 106. See also Kopp, "Geschichte der Chemie," iii, 200 and 204.

"It is evident," he writes,* "that atmospheric air is not the most suitable to increase the action of fire, and that, if we drive a current of air upon ignited fuel by means of bellows, three parts of injurious, or at least useless, gas are driven in for one part of the serviceable kind of air, and that, therefore, if the latter could be used for combustion in a pure state, the action of the fire would be much enhanced. This idea has doubtless occurred to many persons prior to myself, and I hear that Archard, the celebrated chemist of Berlin, has carried it into application ;† but it is still needful to devise a cheap and convenient apparatus."

For this purpose, Lavoisier used at first bladders fitted with tubes and taps. "I made," he continues, "with a knife, a hole three to four lines deep in a large piece of charcoal, and laid in it 6 grs. of platinum, set fire to the charcoal at an enameler's lamp by means of a blowpipe, opened the jet of my apparatus, and blew pure oxygen into the hollow. The charcoal burnt very rapidly, with detonation as it produces with melted saltpeter, and with a dazzling brilliance; and in a few moments the platinum melted into granules, which then united into a ball. The fusion was equally successful, whether the ordinary platinum of commerce was taken or such as had been previously freed from magnetic particles by means of a magnet. Hitherto, platinum has not been melted."

Lavoisier improved his apparatus in the same year,‡ in conjunction with Meusnier, and produced a gasometer consisting of two boxes, and which on a small scale much resembled those now in use at gasworks. About the same time, Saron constructed two blowpipes (*chalumeaux*), one of which delivered oxygen and the other hydrogen. By their means, however, Lavoisier did not succeed in fusing platinum.‖ He hoped, however, to construct an improved blow pipe, in which the oxygen should surround the hydrogen, and thus was developed the plan of the oxyhydrogen blowpipe, which has rendered such essential service in the metallurgy of platinum and in soldering lead.

* "Memoire sur un Moyen d'Augmenter Considérablement l'Action du Feu et de la Chaleur dans les Operations Chimiques."—"Oeuvres de Lavoisier ii, 425.

† *Memoiren der Berliner Academie*, 1779. "Sur un Nouveau Moyen de Produire avec une très Petite Quantité de Charbons une Chaleur," etc.

‡ Lavoisier, "Oeuvres," ii, 432.

‖ Lavoisier, "Oeuvres," ii, 430.

The application of oxygen for melting platinum remained dormant until, in 1857 to 1859, Deville and Debray made known their important investigations * on the platinum metals, and introduced the industrial fusion of platinum. The autogenous soldering of platinum, and the production of fused ingots on the large scale, was first carried out by Johnson, Matthey, & Co., of London, and also by Heraeus, of Hanau, in Germany.

Debray's and Deville's experiments led, above all, to the discovery of a refractory material for crucibles and furnaces. For this purpose quick-lime offered itself, which has the further advantage of retaining the heat as completely as possible. The chemists aboved-named increased the heat further by leading the flame from above directly upon the surface of the metal, and determined the amounts of oxygen and hydrogen theoretically and practically necessary for melting 2 kilos. of platinum, *i. e.*, by calculation, 55 liters of oxygen and 110 of hydrogen. The amount actually fused was more than 1 kilo, so that —a highly favorable result—not 50 per cent. of the heat produced was wasted. These experiments had a further bearing upon the industrial history of oxygen, as they led to the comparison of the cost of the methods of its production and to the search for a less expensive process. We may divide the known methods into chemical and mechanical, subdividing the former into continuous and interrupted procedures.

Up to this time, the following methods of preparation were either in use, or had been proposed :—The original process of Priestley, heating oxide of mercury, of course, the most expensive, and the least suited for technological purposes; then Scheele's method, treatment of peroxide of manganese with sulphuric acid, the result being manganous sulphate and oxygen. On the large scale, since the investigations of Berthier in 1822, this was replaced by the simple ignition of manganese, and finally the action of heat upon the chlorate of potash. The last-mentioned process, in spite of its costliness, has become established for laboratory operations, as being convenient and requiring only a small supply of heat, although it has frequently occasioned explosions when the gas was being too rapidly liberated. To prevent such accidents, it has been repeatedly proposed to mix manganese

* Deville and Debray, 1859, *Ann. Chim. Phys.*, lvi, 385. *Dingler's Polyt. Journ.* cliv, 130, 199, 287, 383.

with the chlorate of potash. Recent accidents, especially a fearful explosion in a pharmaceutical laboratory in Paris, induced Debray and Bourgoin* to make known the precautions used in Deville's laboratory. Manganese, or the red manganoso-manganic oxide (Mn_3O_4), which is more easily obtained in a state of purity, is mixed with the chlorate of potash in equal weights, and the iron retort is heated in a furnace filled with fuel in such a manner that the fire may be kindled at the top. Schwartz † made known accidents occasioned by the use of manganese adulterated with lampblack, or by the accidental use of the sulphide of atimony instead of manganese, and he therefore very justly recommends that oxygen gas mixture should be previously tested by heating a portion upon platinum foil. Munck ‡ proposed to use oxide of iron instead of manganese, as being more easily distinguished.

Scheele's process—the mutual action of manganese and sulphuric acid—has the disadvantage that the glass is often broken by the congelation of the manganous sulphate. To prevent this, Wagner ‖ proposes to use, instead of sulphuric acid, bisulphate of soda. An easily fusible double salt is thus formed which does not break the glass as it cools. Pure peroxide of manganese, when thus treated, evolves 18 per cent. of oxygen, but only 12 per cent. if ignited, when it is converted into sesquioxide. Nevertheless, the latter process is the more economical. Deville and Debray§ calculate the expense according to the source of the manganese, as follows:—

Ten kilos. of Manganese from	Cost.	Price of 1 cubic metre of O.
	Francs.	Francs.
Romaneche, . . .	10	4·86
Spain, . . .	16	3·45
Pyrenees, . . .	18	3·86
Giessen, . . .	27	4·87
Italy, ...	40	5·98

The trifling value of the residual sesquioxide which contains iron, and is therefore useless in the glass manufacture, is not taken into

* Debray and Bourgoin, *Ber. Chem. Ges. zu Berlin*, 1870, 240.

† Schwartz, *Breslauer Gewerbeblatt*, 1865, 7.

‡ Munck, *Pohl's Lehrbuch der Technologie Wein*, 1865, 186

‖ Wagner, *Jahresberichte*, 1866, 198.

§ Deville and Debray, *Comptes Rendus*, li, 822,

account. This calculation dates from the time when the re-oxidation of manganese was still an unsolved problem. If the price of oxygen obtained from manganese ranges from 3·45 to 5·98 francs it is cheaper by more than one-half than that procured from chlorate of potash, which Dupré * calculates at 10 francs.

Deville and Debray † found a much cheaper source in sulphuric acid, which, at elevated temperatures, is resolved into water, sulphurous acid and water. Retorts containing 5 liters of very infusible glass were partially filled with platinum foil, or with fragments of brick, and heated to redness, whilst sulphuric acid was allowed to flow in in a slender stream. The escaping gases are led through a cooling apparatus in order to condense sulphuric acid, and into water to remove sulphurous acid. By this process 2·436 kilos. of sulphuric acid of the sp. gr. 1·827 yielded 240 litres of oxygen at the expense of 1 franc per cubic meter. On its application the cost of smelting platinum was from 20 to 30 centimes per kilo.

According to a paragraph by Moigno ‡ the firm of José de Susine & Co., of Paris, prepared by this process oxygen at 0·85 franc per cubic meter, re-converting the sulphurous acid into sulphuric acid.

Instead of the free acid Deville and Debray propose the use of sulphate of zinc; 100 kilos. of the anhydrous salt yielded in their experiments 6.8 cubic meters of oxygen,—far more than the best black oxide of manganese—22 kilos. sulphurous acid gas, and 51 kilos. oxide of zinc.

Wagner's statement|| must be noted that, in the year 1867, both these methods were not carried out in Deville's laboratory, perhaps because the development of sulphurous acid complicated their execution; in fact, they have both been left in the background in industrial practice. As an attempt in that direction, we must notice the procedure of Archereau,§ who employed sulphuric acid in its cheapest combination, gypsum. He maintained that, by heating ground gypsum with sand, he could obtain silicate of lime, whilst sulphurous acid was set free, which he (as also Susini) chiefly condensed by a

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* Dupré, *Compt. Rend.*, lv, 736.

† Deville and Debray, *Compt. Rend.*, li, 822.

‡ *Les Mondes*, 1867, p. 494.

|| Wagner, *Jahresberichte*, 1867, 216.

§ Archereau, *Dingler's Polyt. Journ.*, clxxviii., 57.

pressure of three atmospheres, and removed the rest by passage through milk of lime. A manufactory on this principle, established at Paris, had but a short career.* The very high temperature required is evidently a hindrance. Probably the oldest source of oxygen, saltpeter, had not been used for the preparation of the gas, for two reasons. On the one hand, the product is largely mixed with nitrogen, and on the other, the temperature required for its decomposition augments the cost of preparation. Webster† overcame the latter difficulty by adding to the nitre oxide of zinc. 20 pounds of soda-saltpeter and 4 pounds of crude oxide of zinc yielded in his hands, 94·676 cubic feet of a mixture of 59 per cent. of oxygen and 41 per cent. of nitrogen, the residue being chiefly oxide of zinc and caustic soda. In this mixture, which is useful for many purposes, the oxygen cost 2·32 francs per cubic meter if the solid residue be neglected; but, if the latter be utilized, the expense of the oxygen falls to 0·78 franc.‡

In all these methods, one of the leading ideas of modern industry, the regeneration of residues, has been neglected. The following proposals are, in this respect, happier, and have, therefore, been partially more successful. To combine the oxygen of the atmosphere chemically with some substance which shall readily give off the combined gas and be again able to take up and give off fresh quantities of oxygen, as is done by the mercury in mercuric oxide; this is the problem which has been solved in the last few years. As early as 1829, Dingler, Junior,‖ observed that both oxide of copper and the peroxides of nickel and cobalt, with an excess of chloride of lime, gave off oxygen, converting the latter substance into chloride of calcium. In 1845, Mitscherlich§ made known the fact that various other metallic oxides, peroxide of manganese, hydrated peroxide of iron, etc., if added to a solution of chloride of lime, occasioned a plentiful liberation of oxygen. In 1865, these observations were renewed by T. H. Fleitmann,** with especial reference to recently prepared sesquioxide, small quantities of which sufficed to decompose completely a concen-

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* Wagner, *Jahresberichte*, 1867, 215.

† Pepper, *Chemical News*, 1862, 218.

‡ Dupré, *Comptes Rendus*, lv., 736.

‖ *Dingler's Polyt. Journ.*, xxvi., 231.

§ Mittscherlich, *Pogg. Ann.*, lviii., 471.

** *Ann. Chem. Pharm.*, cxxxiv., 64.

trated solution of chloride of lime into chloride of calcium and oxygen gas. He recommended, in practice, a solution of chloride of lime concentrated as much as possible, and clarified by filtration or deposition to prevent frothing, and then mixed with 0·1 to 0·5 per cent. of its contents of sesquioxide of cobalt, and heated from 70° to 80°. On employing chloride of lime at 35 per cent., he obtained oxygen in a regular stream, to 25 or 30 times the volume of the liquid. Other observers, especially F. Varrentrapp,* confirmed these results, and recommended the industrial adoption of the process. The sesquioxide of cobalt does not require to be manufactured in advance. Any salt of cobalt in solution serves the same purpose, and the sesquioxide settles to the bottom and can be used again in fresh operations.

For the same reason, a cheaper oxide, as for instance, oxide of copper, which Bottger proposes,† offers but little advantage, especially as a higher temperature is required for its decomposition.‡ The trouble of preparing a clear solution of chloride of lime may be dispensed with if, as Stolba suggests, a piece of paraffin of the size of a pea be added to the turbid solution.|| The thin layer of oil upon the surface prevents frothing. One difficulty yet remains to be removed. Chloride of lime requires considerable quantities of water for solution, and large vessels are, therefore, required for preparing moderate quantities of oxygen. A. Winkler,§ therefore, dispensed with chloride of lime, by using a thick milk of lime with a little salt of cobalt, and treating the mixture with chlorine. By means of this modification, a larger volume of oxygen is evolved with the same vessels, and all danger of frothing over is avoided.

The part played by the metallic oxide in these methods is readily intelligible. It serves as a carrier of oxygen, passing alternately to a higher, readily decomposable, stage of oxidation, and then returning to its original state. The hypochlorous acid of the chloride of lime converts the sesquioxide of cobalt into an unstable cobaltic acid, which is immediately resolved into sesquioxide of cobalt and oxygen.

$$Co_2O_3+3[CaCl(OCl)]=3CaCl_2+2CoO_3=Co_2O_3+O_3.$$

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* *Mittheilungen f. d. Gewerbe Vereins des Herzogthums Braunschweig*, 1865–66, 72.

† Böttger, *Journ. Prakt. Chem.*, xcv., 375.

‡ Reinsch, *Neue Jahr. Pharm.*, xxiv., 94.

|| Stolba, *Journ. Prakt. Chem.*, xcvii,, 309.

§ A. Winkler, *Journ. Prakt. Chem.*, xcviii., 340.

Thus, one part of the above-stated problem is solved, and the developer of oxygen is re-formed by the very act of developing oxygen. Still the oxygen is obtained, not from the atmosphere, but from the chloride of lime. The solution of chloride of calcium formed must be removed, and replaced by milk of lime. The process, therefore, is not continuous, and in this respect, there is still room for economic simplification.

This, also, has been achieved, and by means of experiments which lead us back from the moist to the dry way. Since 1851,* Boussingault has brought baryta into use as a bearer of oxygen, heating it to redness in porcelain tubes, and treating it with moist air free from carbonic acid, by which it is converted into peroxide of barium. By means of a current of watery vapor, it is re-converted into hydrate of baryta, and oxygen is liberated. An addition of lime or magnesia prevents any incipient fusion, and 75 grams of baryta yield on each operation 4 to 5 liters of oxygen. Gondolo† improved this method in 1868, replacing the porcelain tubes with iron ones, protected by magnesia within and by asbestos without, and laid in suitable furnaces, whose temperature was regulated by dampers, and adding to the baryta a little manganate of potash as well as lime and magnesia. In this manner as many as 122 alternate oxidations and deoxidations were conducted in the same tube. Whether, however, it be due to the high temperature, or to other drawbacks which stand in the way of the industrial application of this method, it has not yet found its way into actual practice.‡

Attention was directed to more sensitive transferrers of oxygen than baryta, and in the first place to chloride of copper. Its property, on exposure to the air, to pass into oxychlorides of various composition, lies at the root of the manufacture of a well known pigment, Brunswick green. In 1855, Vogel proposed the action of hydrochloric acid upon oxychlorides of copper as a source of chlorine.|| Mallet§ examined these bodies more closely, and in 1867 and 1868, proposed a

* Boussingault, *Comptes Rendus*, xxxii., 261 and 821,

† Gondolo, *Comptes Rendus*, lxvi., 488.

‡ Robbin, *Pogg. Ann.*, cxxii., 256,

|| Vogel, Wagner, *Jahresberichte*, 1861, 177.

§ Mallet, *Comptes Rendus*, lxiv., 286, and lxvi., 349.

method for the industrial preparation of chlorine and oxygen. He found that cuprous chloride is converted into oxychloride by a current of steam at from 100° to 200° C., which, in contract with hydrochloric acid, is immediately resolved into cupric chloride and free chlorine, but which, if heated to 400°, gives off all its oxygen. One kilo. of cuprous chloride, yields 28 to 30 liters of oxygen. In experiments on the large scale, 100 kilos. of cuprous chloride yielded either 3 to 3½ cubic meters of oxygen, or 6 to 7 cubic meters of chlorine. As four or five such operations can be conducted daily, 200 to 300 kilos. of cuprous chloride could be made to yield daily, 15 to 18 cubic meters of oxygen. The requisite apparatus consists of rotatory cast iron retorts lined with clay, which contain the cuprous chloride mixed with one-third sand or kaolin to diminish its fusibility. This process was carried out in Cologne in 1871.* A company established at Paris for the utilization of the process flourished for a short time only,† probably because it was superseded by an analogous process.

We refer to the method which has been developed since 1867‡ by the suggestive inventor, Tessié du Motay. Its transferrer of oxygen is the black oxide of manganese, and it is based upon the following reactions: Hydrate of soda, according to Mittscherlich, if heated to dull redness in contact with air and black oxide of manganese, yields manganate of soda and water—

$$4NaOH+2MnO_2+2O=2Na_2MnO_4+2H_2O.$$

Manganate of soda at the same temperature, in a current of dry superheated steam, is resolved again into hydrate of soda, sesquioxide of manganese, and free oxygen—

$$2Na_2MnO_4+2H_2O=4NaOH+Mn_2O_3+3O.$$

The only condition, then, is to free the superheated air previously from carbonic acid, in order to obtain a mixture which shall be perpetually efficient. This method has been found satisfactory on repeated scrutiny, and has been applied on the large scale at Comines (near Lille), at Pantin (near Paris), at New York, Brussels, and Vienna. Bothe‖ reports that a melting of 60 parts of dry carbonate of soda

* Phillips, "Der Sauerstoff" (Berlin, 1871), 22.

† Wagner, *Jahresberichte*, 1867, 215.

‡ Tessié du Motay, *Institut*, 1868, 48.

‖ Bothe, *Zeitschr. d. Vereins Deutsch. Ing.*, 1867, 334.

with 40 parts of peroxide of manganese, at 95 per cent., yielded, according to analysis, 74·62 of manganate of soda, and that 40 kilos. of this substance, which, according to theory, should yield 2036 cubic decimeters of oxygen, actually produced 1800, or 90 per cent. of the calculated yield. He recommended the process as easy of execution. The most complete description has been given by Pourcel.* According to him, Tessié du Motay employs for retorts cast iron elipsoids, which lie horizontally side by side, and are divided by a grate into two unequal portions parallel with their axis. Upon the grate are spread in each retort, 350 kilos. of manganate of soda, or the corresponding reduced mixture of soda and manganese, in such a manner that its thickness amounts to 0·6 of a metre, and the empty space above and below the mass is as small as possible. In Comines, where five such retorts are in action, the daily production amounted to 140 cubic meters of oxygen, with an expenditure of 450 kilos. of coal for heating the retorts, and 150 kilos. for the steam-engine.

(To be continued.)

THE MECHANICAL ACTION OF LIGHT.

By Wm. Crookes, F.R.S., etc.†

Some experiments illustrating the mechanical action of Light, which I have recently exhibited before the Fellows of the Royal Society, having attracted considerable attention, I propose to give here a description of some of the instruments which my researches have enabled me to construct. But, to render the subject more intelligible, it will be necessary to give a brief outline of the researches which I have been carrying on for the last three or four years, so that the reader may see the gradual steps which have led up to the full proof that Radiation is a motive power.

The experiments were first suggested by some observations made when weighing heavy pieces of glass apparatus in a chemical balance, enclosed in an iron case from which the air could be exhausted. When

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* Pourcel, "Mémoires de la Société des Ingénieurs Civiles," P——, 1873.

† The *Quarterly Journal of Science.*

the substance weighed was of a temperature higher than that of the surrounding air and the weights, there appeared to be a variation of the force of gravitation. Experiments were thereupon instituted to render the action more sensible and to eliminate sources of error.*

My first experiments were performed with apparatus made on the principle of the balance. An exceedingly fine and light arm was delicately suspended in a glass tube by a double-pointed needle; and at the ends were affixed balls of various materials. Amongst the substances thus experimented on, I may mention pith, glass, charcoal, wood, ivory, cork, selenium, platinum, silver, aluminium, magnesium, and various other metals.

The most delicate apparatus for general experiment was made with a straw beam having pith masses at the end. The general appearance of the apparatus is shown in Fig. 1.

a is the tube belonging to the Sprengel pump.† *b* is the desiccator, full of glass beads moistened with sulphuric acid. *c* is the tube containing the straw balance with pith ends; it is drawn out to a contracted neck at the end connected with the pump, so as to readily admit of being sealed off at any stage of the exhaustion. *d* is the pump-gauge, and *e* is the barometer.

The whole being fitted up as here shown, and the apparatus being full of air to begin with, I passed a spirit-flame across the lower part of the tube at *b*, observing the movement by a low-power micrometer; the pith ball (*a b*) descended slightly, and then immediately rose to considerably above its original position. It seemed as if the true action of the heat was one of attraction, instantly overcome by ascending currents of air. A hot metal or glass rod and a tube of hot water applied beneath the pith ball at *b* produced the same effect as the flame; when applied above at *a*, they produced a slight rising of the ball. The same effects take place when the hot body is applied to the other end of the balanced beam. In these cases, air currents are sufficient to explain the rising of the ball under the influence of heat.

In order to apply the heat in a more regular manner, a thermometer was inserted in a glass tube, having at its extremity a glass bulb about $1\frac{1}{2}$ inches diameter; it was filled with water and then sealed up (see Fig. 2). This was arranged on a revolving stand, so that by means

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* "On the Atomic Weight of Thallium," Phil. Trans., 1873, vol. clxiii, p. 287.

† For a full description of this pump, with diagrams, see Phil. Trans., 1873, vol clxiii, p. 295.

Fig. 1.

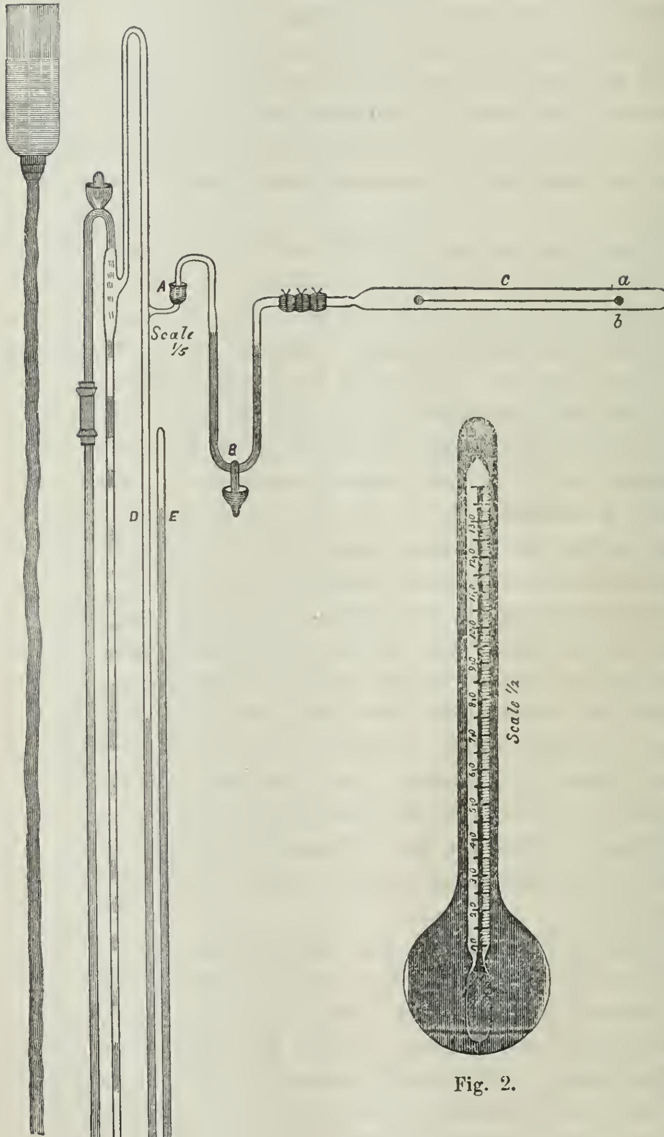

Fig. 2.

of a cord, I could bring it to the desired position without moving the eye from the micrometer. The water was kept heated to 70°C., the temperature of the laboratory being about 15°C.

The barometer being at 767 millims., and the gauge at zero, the hot bulb was placed beneath the pith ball at *b*. The ball rose rapidly. The source of heat was then removed, and as soon as equilibrium was restored, I placed the hot water bulb above the pith ball at *a*, when it rose again, more slowly, however, than when the heat was applied beneath it.

The pump was then set to work; and when the gauge was 147 millims. below the barometer, the experiment was tried again; a similar result, only more feeble, was obtained. The exhaustion was continued, stopping the pump from time to time to observe the effect of heat, when it was seen that the effect of the hot body regularly diminished as the rarefaction increased, until, when the gauge was about 12 millims. below the barometer, the action of the hot body was scarcely noticeable. At 10 millims. below it was still less; whilst when there was only a difference of 7 millims. between the barometer and the gauge, neither the hot water bulb, the hot rod, nor the spirit-flame caused the ball to move in an appreciable degree.

The inference was almost irresistible that the rising of the pith was only due to currents of air, and that at this near approach to a vacuum the residual air was too highly rarefied to have power in its rising, to overcome the inertia of the straw beam and the pith balls. A more delicate instrument would doubtless show traces of movement at a still nearer approach to a vacuum; but it seemed evident that when the last trace of air had been removed from the tube surrounding the balance—when the balance was suspended in empty space only—the pith ball would remain motionless, wherever the hot body were applied to it.

I continued exhausting. On next applying heat underneath, the result showed that I was far from having discovered the law governing these phenomena; the pith ball rose steadily, and without that hesitation which had been observed at lower rarefactions. With the gauge 3 millims. below the barometer, the ascension of the pith when a hot body was placed beneath it, was equal to what it had been in air of ordinary density; whilst with the gauge and barometer level, its upward movements were not only sharper than they had been in air, but

they took place under the influence of far less heat—the finger, for example, instantly repelling the ball to its fullest extent.

To verify these unexpected results, air was gradually let into the apparatus, and observations were taken as the gauge sank. The same effects were produced in inverse order, the point of neutrality being when the gauge was about 7 millims. below a vacuum.

A piece of ice produced exactly the opposite effect to a hot body.

The presence of air having so marked an influence on the action of heat, an apparatus was fitted up in which the source of heat (a platinum spiral rendered incandescent by electricity) was inside the vacuum-tube instead of outside it as before; and the pith balls of the former apparatus were replaced by brass balls. By careful manipulation and turning the tube round, I could place the equipoised brass ball either over, under, or at the side of the source of heat. With this apparatus I tried many experiments, to ascertain more about the behavior of the balance during the progress of the exhaustion, both below and above the point of no action, and also to ascertain the pressure corresponding with this critical point.

In one experiment, which is described in detail in my paper on this subject before the Royal Society,* the pump was worked until the guage had risen to within 5 millims. of the barometric height. On arranging the ball above the spiral and making contract with the battery, the attraction was still strong, drawing the ball downwards a distance of 2 millims. The pump continuing to work, the guage rose until it was within 1 millim. of the barometer. The attraction of the hot spiral for the ball was still evident, drawing it down when placed below it, and up when placed above it. The movement, however, was much less decided than before; and in spite of previous experience the inference was very strong that the attraction would gradually diminish until the vacuum was absolute, and that then, and not till then, the neutral point would be reached. Within 1 millim. of a vacuum there appeared to be no room for a change of sign.

The guage rose until there was only $\frac{1}{2}$ a millim. between it and the barometer. The metallic hammering heard when the rarefaction is close upon a vacuum commenced, and the falling mercury only occasionally took down a bubble of air. On turning on the battery current, there was the faintest possible movement of the brass ball (towards the spiral) in the direction of attraction.

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* Phil. Trans., 1874, vol. clxiv, p. 501.

The working of the pump was continued. On next making contact with the battery, no movement could be detected. The red-hot spiral neither attracted nor repelled. I had arrived at the critical point. On looking at the guage I saw it was level with the barometer.

The pump was now kept at full work for an hour. The gauge did not rise perceptibly; but the metallic hammering sound increased in sharpness, and I could see that a bubble or two of air had been carried down. On igniting the spiral, I saw that the neutral point had been passed. The sign had changed, and the action was one of faint but unmistakable *repulsion*. The pump was still kept going, and an observation was taken from time to time during several hours. The repulsion continued to increase. The tubes of the pump were now washed out with oil of vitriol,* and the working was continued for an hour.

The action of the incandescent spiral was now found to be energetically *repellent*, whether it was placed above or below the brass ball. The fingers exerted a repellent action, as did also a warm glass rod, a spirit-flame, and a piece of hot copper.

In order to decide once for all whether these actions really were due to air-currents, a form of apparatus was fitted up which—whilst it would settle the question indisputably—would at the same time be likely to afford information of much interest.

By chemical means I obtained in an apparatus a vacuum so nearly perfect that it would not carry a current from a Ruhmkoff's coil when connected with platinum wires sealed into the tube. In such a vacuum the repulsion by heat was still found to be decided and energetic.

I next tried experiments in which the rays of the sun, and then the different portions of the solar spectrum, were projected on to the delicately suspended pith ball balance. *In vacuo* the repulsion by a beam of sunlight is so strong as to cause danger to the apparatus, and resembles that which would be produced by the physical impact of a material body.

A simpler form of the apparatus for exhibiting the phenomena of attraction in air and repulsion in a vacuum consists of a long glass

* This can be effected without interfering with the exhaustion.

tube, *a b* (Fig. 3), with a globe, *c*, at one end. A light index of pith, *d e*, is suspended in this globe by means of a cocoon fiber.

Fig. 3.

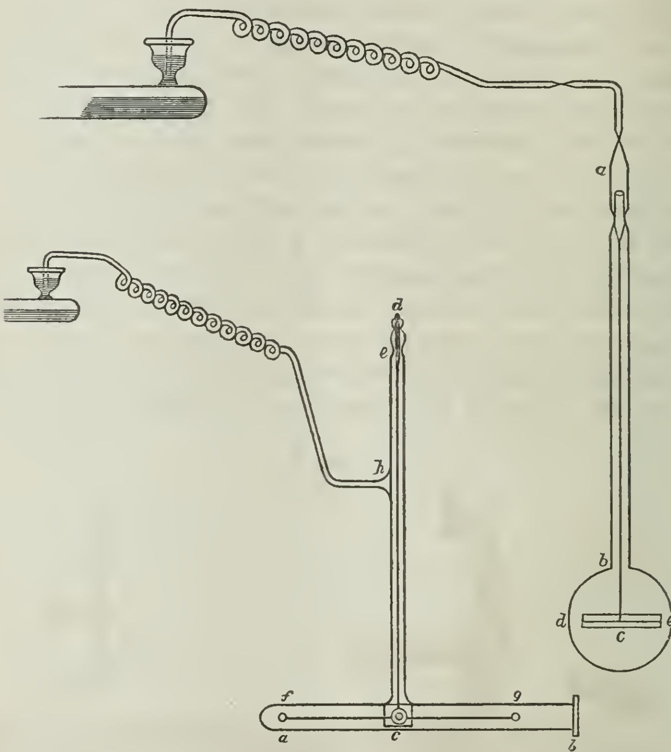


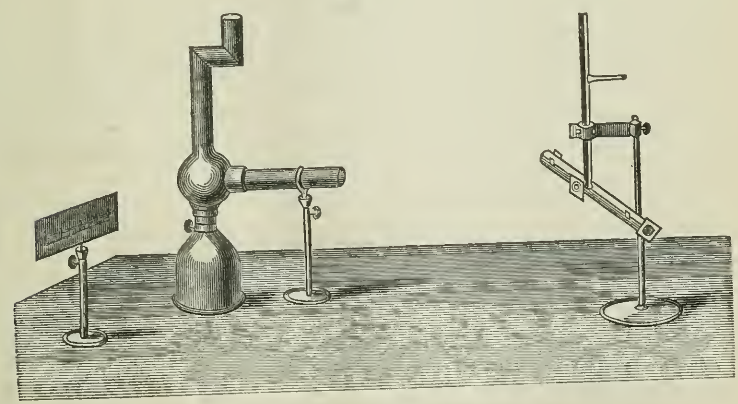
Fig. 4.

When the apparatus is full of air at ordinary pressure, a ray of heat or light falling on one of the extremities of the bar of pith gives a movement indicating attraction. When the apparatus is exhausted until the barometric gauge shows a depression of 12 millims. below the barometer, neither attraction nor repulsion results when radiant light or heat falls on the pith, but when the vacuum is as good as the pump will produce, strong repulsion is shown when radiation is allowed to fall on one end of the index. An apparatus of this kind constructed with the proper precautions, and sealed off when the vacuum is perfect, is so sensitive to heat that a touch with the finger

on a part of the globe near one extremity of the pith, will drive the index round over 90°, while it follows a piece of ice as a needle follows a magnet. With a large bulb, very well exhausted and containing a suspended bar of pith, a somewhat striking effect is produced when a lighted candle is placed about 2 inches from the globe. The pith bar commences to oscillate to and fro, the swing gradually increasing in amplitude until the dead centre is passed over, when several complete revolutions are made. The torsion of the suspending fiber now offers resistance to the revolutions, and the bar commences to turn in the opposite direction. This movement is kept up with great energy and regularity as long as the candle burns.

For more accurate experiments I prefer making the apparatus differently. Fig. 4 represents the best form. *a b* is a glass tube, to which is fused at right angles another narrower tube, *c d;* the vertical tube is slightly contracted at *e*, so as to prevent the solid stopper *d*—which just fits the bore of the tube—from falling down. The lower end of the stopper, *d e*, is drawn out to a point; and to this is cemented a fine glass thread about 0·001 inch diameter, or less, according to the torsion required.*

Fig. 5.



At the lower end of the glass thread an aluminium stirrup and a concave glass mirror are cemented, the stirrup being so arranged that

* Some of the glass fibers used in these torsion balances are so fine, that when one end is held between the fingers, the other portion floats about like a spider's thread and frequently rises until it takes a vertical position.

it will hold a beam, $f g$, having masses of any desired material at the extremities. At c in the horizontal tube is a plate glass window cemented on to the tube. At b is also a piece of plate glass cemented on. Exhaustion is effected through a branch tube, h, projecting from the side of the upright tube. This is sealed by fusion to the spiral tube of the pump. The stopper $d e$ and the glass plates c and b are well fastened with a cement of resin and beeswax.

The advantage of a glass-thread suspension is that the beam always comes back to its original position.

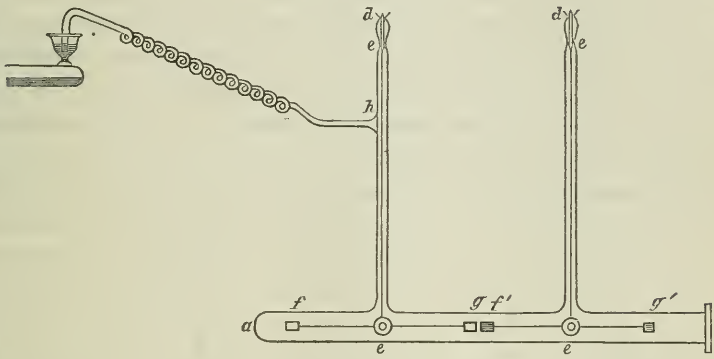
An instrument of this sort, perfectly exhausted and then sealed off, is shown at work in Fig. 5. It has pith plates at the extremities of the torsion beam. A ray of light from the lamp is thrown on to the central mirror, and thence reflected on to the graduated scale. The approach of a finger to either extremity of the beam causes the luminous index to travel several inches, showing repulsion. A piece of ice brought near causes the spot of light to travel as much in the opposite direction. In order to ensure the luminous index coming accurately back to zero, extreme precautions must be taken to keep all extraneous radiation from acting on the torsion-balance. The whole apparatus is closely packed round with a layer of cotton-wool about 6 inches thick, and outside this is arranged a double row of Winchester quart bottles filled with water, spaces only being left for the radiation to fall on the balance and for the index ray of light to get to and from the mirror.

However much the results may vary when the vacuum is imperfect, with an apparatus of this kind they always agree among themselves when the residual gas is reduced to the minimum possible; and it is of no consequence what this residual gas is. Thus, starting with the apparatus full of various vapors and gases, such as air, carbonic acid, water, iodine, hydrogen, ammonia, etc., there is not found at the highest rarefaction, any difference in the results which can be traced to the residual gas. A hydrogen vacuum appears the same as a water or an iodine vacuum.

The neutral point for a thin surface of pith being low, and that for a moderately thick piece of platinum being high, it follows that at a rarefaction intermediate between these two points pith will be repelled, and that platinum will be attracted by the same beam of radiation. This has been proved experimentally. An apparatus

showing simultaneous attraction and repulsion by the same ray of light is illustrated in Fig. 6.

Fig. 6.



The pieces fg on the end of one beam consist of platinum foil exposing a square centimeter of surface, whilst the extremities $f'\,g'$ on the other beam consist of pith plates of the same size. A wide beam of radiation thrown in the centre of the tube on to the plates gf' causes g to be attracted and f' to be repelled, as shown by the light reflected from the mirrors, $c\,c'$. The atmospheric pressure in the appartus is equal to about 40 millims. of mercury.

In a torsion apparatus similar to the one shown in Figs. 4 and 5, I have submitted variously colored discs to the action of the different rays of the spectrum. The most striking results, as yet, have been obtained when the different rays of the spectrum were thrown on white and on black surfaces. The result was to show a decided difference between the action of light and of radiant heat. At the highest exhaustions dark heat from boiling water acts almost equally on white pith and on pith coated with lampblack, repelling either with about the same force. The action of the luminous rays, however, is different. These repel the black surface more energetically than they do the white surface and consequently, if in such an apparatus as is shown at Fig. 4, one disc of pith is white and the other is black, an exposure of both of them to light of the same intensity will cause the torsion thread to twist around, owing to the difference of repulsion exerted on the black and the white surface. If, in the bulb apparatus shown in Fig. 3, the halves of the pith bar are alternately white and lampblacked, this differential action will produce rapid

rotation in one direction, which keeps up until stopped by the torsion of the suspending fiber.

Taking advantage of this fact I have constructed an instrument which I have called the Radiometer, shown in section and plan at Figs. 7 and 8. It consists of four arms, of some light material, suspended on a hard steel point resting in a jewel cup, so that the arms are able to revolve horizontally upon the centre pivot, in the same manner as the arms of Dr. Robinson's anemometer revolve. To the extremity of each arm is fastened a thin disc of pith, white on one side and lampblacked on the other, the black surfaces of all the discs facing the same way. The whole is enclosed in a thin glass

Fig. 7.

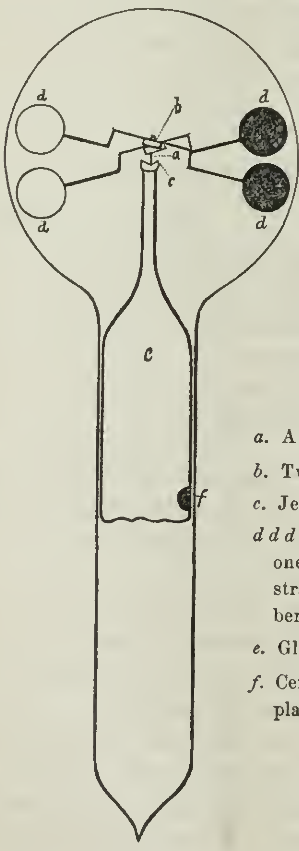
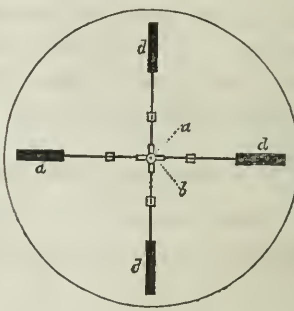


Fig. 8.



a. A very fine needle point.

b. Two pieces of straw.

c. Jewel cup.

d d d d. Four pith discs, blackened on one side. The arms between the straw in the centre and the discs are bent glass fibers.

e. Glass support holding cup.

f. Cement to keep the support *e* in its place.

globe, which is then exhausted to the highest attainable point and hermetically sealed.

The arms of this instrument rotate with more or less velocity under the action of radiation, the rapidity of revolution being directly proportional to the intensity of the incident rays. Placed in the sun or exposed to the light of burning magnesium, the rapidity is so great that the separate discs are lost in a circle of light. Exposed to a candle 20 inches off another instrument gave one revolution in 182 seconds; with the same candle placed at a distance of 10 inches off the result is one revolution in 45 seconds; and at 5 inches off one revolution was given in 11 seconds. Thus it is seen that the mechanical action of radiation is inversely proportional to the square of the distance. At the same distance 2 candles give exactly double, and 3 candles give three times, the velocity given by 1 candle, and so on up to 24 candles. A small Radiometer was found to revolve at the velocities shown in the following table, when exposed to the radiation of a standard candle 5 inches off.

TIME REQUIRED FOR ONE REVOLUTION.

Source of Radiation.	Time in Seconds.
1 candle, 5 inches off, behind green glass, ...	40
" 5 " " blue "	38
" 5 " " purple "	28
" 5 " " orange "	26
" 5 " " yellow "	21
" 5 " " light red "	20

In diffused daylight the velocity was one revolution in from 1·7 seconds to 2·3 seconds, according to the intensity of the incident rays. In full sunshine, at 10 A. M., it revolved once in 0·3 second, and at 2 P. M., once in 0·25 second.

When heat is cut off by allowing the radiation to pass through a thick plate of alum, the velocity of rotation is somewhat slower, and when only dark heat is allowed to fall on the arms (as from a vessel of boiling water) no rotation whatever is produced.

In all respects, therefore, it is seen that the Radiometer gives indications in strict accordance with theory.

Several radiometers, of various constructions as regards details, but all depending on the above-named discovery, have been exhibited

at the Royal Society, where their novelty and unexpected indications excited a considerable amount of interest.

This form of instrument is of too recent a construction for me to be able to do more than draw brief attention to a few of the many uses for which it is applicable.

By timing the revolutions of the instrument when exposed direct to a source of light—a candle, for instance—the total radiation is measured. If a screen of alum is now interposed, the influence of heat is almost entirely cut off, the velocity becomes proportionately less, and the instrument becomes a photometer. By its means photometry becomes much simplified; flames the most diverse may readily be compared between themselves or with other sources of light; a "standard candle" can now be defined as one which at x inches off, causes the radiometer to perform y revolutions per minute, the values of x and y having previously been determined by comparison with some ascertained standard; and the statement that a gas-light is equal to so many candles, may, with more accuracy, be replaced by saying that it produces so many revolutions.

To photographers the radiometer will be invaluable. As it will revolve behind the orange-colored glass used for admitting light into the so-called dark room, it is only necessary to place one of these instruments in the window to enable the operator to see whether the light entering his room is likely to injure the sensitive surfaces there exposed; thus, having ascertained by experience that his plates are fogged, or his paper injured, when the revolutions exceed, say, ten a minute, he will take care to draw down an extra blind when the revolutions approach that number. Still more useful will the radiometer be in the photographic gallery. Placing an instrument near the sitter at the commencement of the day's operations, it is found that, to obtain a good negative, the lens must be uncovered—not for a particular number of seconds—but during the time required for the radiometer to make, say, twenty revolutions. For the remainder of the day, therefore, assuming his chemicals not to vary, the operator need not trouble himself about the variation of light; all he has to do is to watch the radiometer and expose for twenty revolutions, and his negatives will be of the same quality,* although at one time it may have taken

* In this brief sketch I omit reference to the occasions in which the ultra violet rays diminish in a greater proportion than the other rays.

five minutes, and at another not ten seconds, to perform the allotted number.

I have long been experimenting in the endeavor to trace some connection between the movements of attraction and repulsion, above alluded to, and the action of gravitation in Cavendish's celebrated experiment. The investigation is not sufficiently advanced to justify further details, but I will give here an outline of one of the results.

I find that a heavy metallic mass, when brought near a delicately suspended light ball, attracts or repels it under the following circumstances:—

I. *When the ball is in air of ordinary density.*

a. If the mass is *colder* than the ball, it *repels* the ball.
b. If the mass is *hotter* than the ball, it *attracts* the ball.

II. *When the ball is in a vacuum.*

a. If the mass is *colder* than the ball, it *attracts* the ball.
b. If the mass is *hotter* than the ball, it *repels* the ball.

The density of the medium surrounding the ball, the material of which the ball is made, and a very slight difference between the temperatures of the mass and the ball, exert so strong an influence over the attractive and repulsive force, and it has been so difficult for me to eliminate all interfering actions of temperature, electricity, etc., that I have not yet been able to get distinct evidence of an independent force (not being of the nature of heat or light) urging the ball and the mass together.

Experiment has, however, shown me that, whilst the action is in one direction in dense air, and in the opposite direction in a vacuum, there is (as I have already pointed out in the experiments described in the commencement of this paper) an intermediate pressure at which differences of temperature appear to exert little or no interfering action. By experimenting at this critical pressure, and at the same time taking all the precautions which experience shows are necessary, it would seem that such an action as was obtained by Cavendish, Reich, and Baily, should be rendered evident.

It is not unlikely that in the experiments here recorded may be found the key of some as yet unsolved problems in celestial mechanics.

In the sun's radiation passing through the quasi vacuum of space, we have the radial repulsive force, possessing successive propagation, required to account for the changes of form in the lighter matter of comets and nebulæ, and we may learn by that action, which is rapid and apparently fitful, to find the cause in those rapid bursts which take place in the central body of our system; but until we measure the force more exactly we shall be unable to say how much influence it may have in keeping the heavenly bodies at their respective distances.

So far as repulsion is concerned, we may argue from small things to great, from pieces of pith up to heavenly bodies; and we find that the repulsion shown between a cold and warm body will equally prevail, when for melting ice is substituted the cold surface of our atmospheric sea in space, for a lump of pith a celestial sphere, and for an artificial vacuum a steller void.

Throughout the course of these investigations I have endeavored to remain unfettered by the hasty adoption of a theory, which, in the early stages af an inquiry, must almost of necessity be erroneous. Some minds are so constituted that they seem impelled to form a theory on the slightest experimental basis. There is then great danger of their becoming advocates, and unconsciously favoring facts which seem to prove their preconceived ideas, and neglecting others which might oppose their views. This is unfortunate, for the mind should always be free to exercise the judicial function, and give impartial weight to every phenomenon which is brought it. *Any* theory will account for *some* facts; but only the true explanation will satisfy *all* the conditions of the problem, and this cannot be said of any theory which has yet come to my mind.

My object at present is to ascertain facts, varying the conditions of each experiment so as to find out what are the necessary and what the accidental accompaniments of the phenomena. By working steadily in this manner, letting each group of experiments point out the direction for the next group, and following up as closely as possible, not only the main line of research, but also the little by-lanes which often lead to the most valuable results, after a time the facts will group themselves together and tell their own tale; the conditions under which the phenomena invariably occur will give the laws; and the theory will follow without much difficulty. The eloquent language of Sir Humphry Davy contains valuable advice, although in

terms somewhat exaggerated. He says,—"When I consider the variety of theories which may be formed on the slender foundation of one or two facts, I am convinced that it is the business of the true philosopher to avoid them altogether. It is more laborious to accumulate facts than to reason concerning them; but one good experiment is of more value than the ingenuity of a brain like Newton's."

A NEW METHOD OF USING PAPER IN PLACE OF GLASS FOR NEGATIVES IN DRY-PLATE PHOTOGRAPHY.

By Leon Warnerke.*

All photographers are aware that photography out of the studio, with the systems now employed, presents certain difficulties which make the process of taking a photograph anything but pleasant. Having, in my photographic excursions, experienced all these inconveniences, I adopted from time to time different improvements; and having now arrived at a very satifactory solution of that all-important question for every photographer engaged out of the studio, I intend to give a full description of my method of working, and illustrate it by practical demonstration.

I scarcely need discuss the question whether the wet or dry system is to be employed for landscape photography. Owing to the great perfection reached in the preparation of collodion and gelatine emulsions, my choice is made, without hesitation, in favor of the dry system.

The first obstruction encountered is the material employed at present for the support to the sensitive film. Glass, notwithstanding the last extremely important discovery of M. de la Bastie, possesses many disadvantages when used in out-door photography. 1. It is heavy. 2. It is bulky in itself, and more so from the necessity of leaving empty space between the plates to prevent contact with the sensitive surface; and, again, from the necessity of having some kind of box

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* Communicated to the South London Photographic Society, at their meeting, June, 1875.

for storing. 3. It is brittle, and consequently requires extra care in transport. But the drawbacks are too numerous to enumerate. They are visible to every photographer, and I hope that experiments I have to perform, while showing the superiority of my new system, will render the disadvantages of glass more salient.

My principal improvement upon the old system is the substitution of paper, cloth, or any flexible material for glass, as support for the sensitive film. In my early experiments (made some five years ago) I applied simply bromized collodion to paper of fine texture sized with starch. But when it was used without substratum, prolonged development or further intensification occasioned discoloration of the paper by the action of the pyrogallic acid, and it consequently was regarded by myself as unsuccessful. But I cannot omit to mention it on the present occasion, for the very important observation made that bromized collodion in contact with the paper is incomparably more sensitive than the same in contact with glass, gelatine, india-rubber, or dammar varnish. The paper used by me was Steinbach's photographic. My experiments were made a long time before Mr. Bolton published his excellent washed emulsion process, so my collodion was made from—

Sulphuric ether, ...	4 ounces.
Alcohol, ...	4 "
Solution of bromine 1 dr. in alcohol 1 oz., .	20 minims.
Suitable pyroxyline, ...	40 grains.
Nitrate of silver (in hot alcohol) or equivalent of oxide of silver, ...	80 grains.

Neither preservative nor washing was necessary.

My next step was using a gelatine substratum between the paper and bromized collodion. In that and in the former case, to avoid discoloration, the developer was free from water. After exposure, the sensitive surface was flowed with a solution of—

Pyrogallic acid, ...	30 grains.
Alcohol, ...	1 ounce.

The excess was returned to the bottle for future use, and the following solution was immediately applied:—

Alcohol, ...	$1\frac{1}{2}$ ounces.
Solution of bromine 1 dr. in alcohol 1 ounce,	10 minims.
Strongest ammonia, ...	2 drachms.

The negative, when finished, was put on the glass, immersed in hot water, and the temporary paper support peeled off. Further experiments prove that great simplification and excellence are secured by the following method:

Preparation of the Negative Film.—I take a sheet of white enameled paper, bend all the sides to form a shallow dish, put it on a glass plate of suitable size, pour in the centre some plain collodion to which a small quantity of paraffine in alcohol was added, and return the excess, after distribution and usual rocking, to the bottle. This, when dry, will leave the paper very easily; but, to avoid this premature occurrence, lines are made with ruling pen or brush and asphalt varnish round the sheet; or, if it is to be cut, each plate is to be delineated with varnish. When this thin coating of collodion is dry, a solution of india-rubber in benzine is applied in a similar way. When dry, another coating of the following collodion is applied.

Ether, ...	20 ounces.
Alcohol, ...	40 "
Castor oil, ...	1 ounce.
Pyroxyline, ...	1 "

After drying, another india-rubber coating, and, lastly, sensitive bromized, bromo-iodo-chloro, or any of the washed collodion emulsions, is applied. When gelatine emulsion is preferred, the last india-rubber coating is omitted. I find the film is equally good when, after first coating of the collodion and paraffine, the following solution of gelatine is applied:—

Gelatine, ...	1 ounce.
Sugar, ...	1 drachm.
Glycerine, ...	$\frac{1}{2}$ "
Water, ...	*quant. suff.*

After it is dry, coatings with collodion and india-rubber follow, and lastly the sensitive emulsion.

In preparing the film, I prefer to build it from several thin coatings, instead of one of requisite thickness, because in that way I can avoid irregularities in thickness occasioned by curling of the paper. For the same reason draining of the solution is made each time from a different corner.

The prepared negative film, with its supporting paper, is cut to the desired size, interleaved with tissue paper for extra security, and preserved from light for use.

Exposure.—For large plates the film is exposed in the usual dark slide behind the glass plate. I choose the glass plate the same thickness as the ground glass in the focussing-frame, and, after reversing the last, I have the sensitive and focussing surfaces to coincide. For small plates, from $6\frac{1}{2}$ by $8\frac{1}{2}$ downwards, I prefer to avoid the use of the glass plate, and attach the paper with sensitive film to some rigid support. Mounting boards answer the purpose very well; but when even this inconsiderable thickness is objectionable, ferrotype plates are an excellent substitute. Negative films with supporting ferrotype plates are so thin that in my excursions last summer I was able to put twenty of these plates in every dark slide; and having with me Howard's tent, attachable to the camera stand, in three dark slides sixty negatives were taken without necessity to repair home, or to have a plate box for those sixty plates.

Development.—For the development, I have to detach one corner of the film with a penknife, and, holding it with two fingers, all the film can be easily detached from the supporting enameled paper.

After this, it is attached to a glass plate of the same size by means of a few drops of water. From that moment the development of the negative is proceeded with in the manner familiar to every photographer. In fact, the film is attached so firmly to the glass plate that there is not the slightest difference in the behavior of that and the old glass plates.

After development, fixing, and washing, some blotting paper is applied to remove the last drop of water. This mode of drying—provoking shuddering in the followers of the old glass system—need not be feared with my films. The final drying—especially when gelatine is used in the formation of the supporting film—must be executed under light pressure, between blotting-paper, in a book or otherwise.

If convenient, it can be dried on the glass plate and varnished, avoiding varnishes requiring heating of the plate; but there is no necessity for varnishing, except to facilitate retouching.

In this stage I have used the process for the last two years with invariable success, and have hundreds of negatives to testify it.

But I must confess I am subject to all the human imperfections. We are never satisfied with what we possess; and this spring, waiting for longer and brighter summer days, and planning my new excursions, the thought of carrying in my pocket Howard's tent, and the

prospect of plunging my head into that tent for changing each plate after the exposure, looked to me an unbearable torture. For consolation I retired to my work room, and, after some time, succeeded in preparing the slide which is intended to remove the last of the impedimenta in my way.

The Dark Slide.—The principal component parts of the new dark slide are two wooden rollers, on one of which the sensitive film, with its supporting paper, or without, is wound, and there is room enough for one hundred negatives. These rollers are placed in a horizontal position within the dark slide, one near the top, and the other near the bottom. Each roller has a metal head on the outside of the slide, by which it can be rotated; by means of these heads the ribbon of sensitive film can be drawn from one roller and wound, after exposure, on the other roller. To secure perfect flatness there is attached to each head a binding screw, permitting the stretching the film smooth when it is in position. A darkened glass plate is fixed near the front of the slide in the plane corresponding with the focussing surface, this glass plate guides the sensitive film in its progress from one roller to the other, and secures its proper position in the focus of the lens.

The back of the dark slide is closed by a hinged door, and the front has a sliding shutter.

Before the sensitive ribbon is attached to the roller it is divided into sections, corresponding with the size of the plates, by black lines drawn in pencil or otherwise, and each section is numbered.

In the sliding shutter is a little window secured with orange glass and spring metallic shutter. Through the orange glass I am able to observe the black lines forming divisions between the plates and corresponding numbers. This permits me to judge of the proper position of each consecutive plate, and tells me which plate is to be exposed; and if any imperfection was observable, which plate to avoid.

The production of negatives in the field with the aid of these improvements is a real enjoyment, because all the hard work is removed, and advantages gained over the old system are numerous.

Volume and weight of plates and apparatus are diminished.

Chance of breakage there is none; chance of abrading the sensitive surface is diminished. I ascribe to the flexibility of the support the greater amount of resistance to rough treatment my film offers.

There is no blurring possible. In application to the panoramic camera, what can offer facility similar to the new film? All costly cylindrical plates and special printing frames are useless; the sensitive film can take any shape in the dark slide, but will be flat in the printing frame.

For printing in carbon, and for all processes requiring reversed negatives, the film negative is ready without preparation. For printing stereoscopic negatives transposition is easy.

For storing negatives, no room, no boxes, or shelves are necessary. Film negatives are not destroyed by atmospheric influences.

Lastly, who can with the glass system, while going to distant lands, dream of taking one thousand plates for his long excursion? But with my film, that number, or one still larger, would not increase the weight of the traveler's luggage more than by a few ounces, and by a few inches the volume.

When I look to the future, the circle of the beneficial effect still widens.

Pliability of the sensitive film can alter optical conditions of our apparatus. Our lenses will be smaller. Definition more perfect. Distortion, spherical aberration, and other optical imperfections diminished. Aperture increased, and consequently exposure shortened.

I conclude with another less important improvement. I do not like the black cloth we use to cover our head when focussing. It gives a mysterious appearance to the operator, and increases the curiosity of the passers-by. Very often it conspires with the wind, without any respect for the head-dress of the operator, or stability of the camera.

In my apparatus I substituted a looking-glass inclined 45° to the ground glass. The image appears in right position, is much brighter, and when shut the frame containing the mirror offers a protection to the ground glass, taking infinitely less room than the black cloth.

Explosion in a Drug Store in Boston.—The *Boston Journal of Chemistry* is of the opinion, the extraordinary explosion which occurred several weeks ago, at the store of Mr. G. D. Dows, in Washington street, in that city, was caused by the vapor of ether, the proprietor having stated that he had in the building, several bottles holding five pounds each of this dangerous agent.

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EDITORIAL.

ITEMS AND NOVELTIES.

Steel in Engineering Practice—During the session of the American Railway Master Mechanic Association, in New York, last May, some experiments were tried to show the comparative strength of cast steel and wrought iron car axles. The experiments appear to have been conducted under the supervision of a committee appointed by the Association, the steel axles having been furnished by the Midvale Steel Works of this city, and the iron axles selected by two members of the Association who desired the test. One lot of iron axles having been forged expressly for the test, at the shops of the gentleman furnishing them. The other lot having been selected by the other gentleman, from the axles used successfully on the road under his charge. A full account of these experiments appeared in the June No. of *The American Artisan* of New York, one of the editors of that paper having been present during the test, and an abstract of the report of the committee was published in the *Railroad Gazette*, of New York. These accounts have been pretty generally copied into other journals, and the experiments have been mostly received as use-

ful and corroborative of the commonly conceived idea of the superior strength of steel. These experiments consisted in letting fall a drop weight of 1600 lbs. from heights of 25 and 35 feet upon the bars of iron and steel which rested on rigid supports placed 3 feet apart, the blow being delivered midway between the supports. While some iron axles stood three or broke at the fourth blow, others broke at the second blow, all of 25 feet fall; and the only steel axle that was broken at all, had three blows of 25 feet and then eight blows from the height of 35 feet.

It may be well to state that the experiments tried in New York were merely a repetition or an exposition of the test adopted by railroads using steel rails in determining the fitness of the steel for railroad purposes. On the reasonable assumption that car axles are submitted to strains requiring stiffness and strength, the test of dropping a weight upon the axle and noting the deflection seems one that would naturally be resorted to. It has, therefore, come to be common practice in ordering steel axles that for one hundred axles ordered, a certain number agreed upon in addition shall be furnished —that this additional number, selected at random from the pile, shall be subjected to the following test: they are placed one at a time upon rigid supports, 3 feet apart; upon the centre of the axle, midway between the supports, a drop weight of 1500 lbs., raised 25 feet, is allowed to fall that distance. The amount of bending caused by the blow is noted. The axle is turned over and another blow from the same height is given, which straightens the axle more or less, so turning the axle between each blow, five blows are given. If all the test-axles stand these blows, the whole lot is accepted; if any of them break, they are all rejected. It is usual to continue the test by blows of 1500 lbs., drop falling 40 feet, until the axles are broken, but all blows after the first five are not considered in the test, so far as the acceptance of the axle is concerned. The trial of the sample axles is supposed to show two things: great strength to resist strains or shocks, and in relation to the amount of bending, the hardness or stiffness of the material. We have seen steel axles break on the second blow, and we have seen them so tough as to require many 40 feet blows to break them. We cannot but think the test the best one possible, under the circumstances.

It has been our intention to comment on these experiments, but we delayed doing so to obtain some definite information from prominent

railroads as to the success of the steel axles in actual use. While engaged in this inquiry, we are met by an article in one of our exchanges, a widely circulated paper, devoted to the iron interest. The article is headed "Steel Railway Axles." After commenting on the nature of the test, the writer says: "If tests made by means of weights subjected an axle to strains in any respect similar to those it encounters in actual service, the results might be considered as conclusive; but they do not; consequently, they are practically valueless as determining whether steel is, or is not, a better material than iron for this use." Again: "It (steel) has from time to time been tried on railroads, and each time abandoned." Then the writer gives his conceptions of the reasons for this, and further on says: "Steel axles have been placed under cars on several different railroads, by gentlemen with whom we are acquainted, and in each case they were abandoned on account of their liability to heat. We know this as a fact, although we do not know the reason for it." These few sentences suggest a treatment of the subject not originally intended. That steel car axles should have been tried and then abandoned, is not surprising, as the cost of steel is even now very much greater than the cost of iron. But that their use should have been abandoned on account of steel being more liable to heat, is a matter of great surprise, and worthy of careful consideration. An inquiry of the leading engineers other than railroad engineers, fails to elicit any experience that would seem to confirm this statement. All that we have heard about steel being liable to heat comes to us in statements somewhat like the article above referred to. That is to say, a mere assertion without any explanations of the conditions under which the trial had been made.

We are told by the writer before alluded to, that a certain size of journal is needed for purposes of lubrication, and that the Master Car-Builders' standard axle has journals $3\frac{3}{4}$ inches diameter, while $3\frac{1}{8}$ inches journals are carrying the load with probably a large margin of strength, but with too little surface for lubrication. Friction being independent of surface within certain limits, the $3\frac{1}{8}$ inches journal in iron, if 5 inches long, may heat, if 6 or 7 inches long may, with its lateral increase of surface, bear the load with safety from heating, and no more frictional resistance, because the diameter, and consequently the surface velocity, has not been increased. Does it not seem reasonable, that with some stronger and stiffer material than iron, the journal may be made to present to

its brass box the amount of surface needed to prevent abrasion in a less diameter and a greater length?

There really seems no reason why the practice of the railroads should differ materially from the practice of the workshop. Car axles revolve under conditions not much worse than the journals and shafts in many machines, and what applies to one applies as much to the other. Any journal, if submitted to too much pressure, will heat. When it does heat from causes other than want of proper lubrication, it is necessary to diminish the load to diminish velocity or to extend the surface under pressure, and in the case of journal, all the things being equal, this extension can best be made useful by extension in length, not in diameter. In an over-hanging journal, as the outside bearing of car axles, an enlargement of diameter increases velocity of the rubbing surfaces, and so increases the frictional resistance inasmuch as the same frictional resistance is acting at a greater distance from the centre. An increase of length, the diameter remaining the same, will diminish the wear without increasing the frictional resistance, inasmuch as the pressure per square inch of surface will be less. When the limit of extension has been reached in such journals on iron shafts of a given strength, no engineer would hesitate to make them still longer if a stronger and stiffer material can be substituted for the iron.

At the same session of the Master Mechanics' Convention at which the steel axles were tested, the form of iron axle recommended by the Master Car-Builders, with a journal $3\frac{3}{4}$ inches diameter, 7 inches long, was not adopted on account of its being larger and heavier than axles doing good service, and on the minds of some who voted, on account of the probable introduction of *steel* axles of a much smaller size than could with safety be made of iron. While some roads, as we are told, have tried and abandoned steel car axles, we know that others have used them, and are using them successfully after a continuous experience of many years.

We have made inquiry of one railroad using steel axles extensively, and found that it alone has nearly twenty-six thousand steel axles in use under its passenger and some freight cars.

It may be asked why roads so using them do not take advantage of the extra strength and stiffness, and reduce the size of the axles, to diminish the dead weight, to diminish the cost, and to diminish the frictional resistance?

We hope soon to be able to present to the readers of this JOURNAL a statement of the experience of this railroad now using 26,000 axles, when it will be seen that that road does use as long a journal, and one of smaller size, than that recommended by the Master Car-Builders' Association, and use it to advantage—made of steel.

That other railroads using steel axles should not at once avail themselves of this advantage of steel, is clear enough to those familiar with the management of roads. Changes in such matters as size of axles involve great changes in many other portions of the cars. Such changes cannot be made at once; a wise policy retains existing sizes, but insures security to passengers by the one of the stronger material in the equipment of passenger cars, and then slowly and surely makes any changes that may seem warranted by experience, not of one year, or two years, but of many years, and as indicated by the clear record of all that experience.

Inasmuch as the steel interests of this country are now so rapidly increasing, we deem an inquiry into its possible displacement of iron in engineering practice of great importance.

We have been informed that steel is entering more and more largely into the construction of locomotives abroad, and if we mistake not, the engines made for a Russian railway last year by the Grant Locomotive Works, of Patterson, N. J., had all parts that could be, made of steel. The rapid advance of the steel manufacture in this country, and the cheapening of the material by improved methods of manufacture, demand a careful consideration of its merits in machine construction.

Steel is now procurable of different qualities, suited to different uses to which it may be applied, and we think the time is near at hand when these qualities will be so well defined as to render their selection by the engineer an easy matter. All the so-called steels, from the finest tool steel down to the qualities which contain so little carbon as to prevent them from showing any hardening properties when heated, and cooled suddenly, seem to have physical properties which readily distinguish them from what we know as bar or wrought iron. The process of manufacture of the low grades of steel is so distinct from the mode of making the wrought iron of commerce, that the so-called steel, containing the least possible amount of carbon, differs materially from the so-called wrought iron which

has been proved to contain the greatest amount of carbon. This difference is marked in regard to strength and stiffness. Steel of all grades, from the softest up to the hardest, behaves differently in the lathe from wrought iron, presenting a more uniform surface when turned or planed, and seldom showing any sign of seam or fiber, as is evidenced in wrought iron.

This finer surface, the greater strength, the greater stiffness, seem to indicate it as *par excellence* the material for machine construction. On railroads steel rails are taking the place of iron, steel tires are encircling the driving wheels, steel sheets form the boilers, and steel connecting rods of light model are in some cases taking the place of the more cumbersome iron ones; but yet we are told that steel car axles are more liable to heat than iron ones.

We have heard the same statement made of steel crank-pins; we have, therefore, included them in our inquiries of railroads using them, and we look for the report now being prepared for us with interest. In machine shop practice we found examples of steel crank-shafts succeeding where iron shafts failed.

As an illustration of this displacement of iron by steel, in engineering practice, mention may be made of the experience of a firm in this city. Some small engines were being constructed, intended to be run at high speed, 900 revolutions per minute. They were fitted with wrought iron crank shafts, carefully fitted to run in phosphor-bronze bearings. In the first trial of one of these engines, the shaft cut so badly as to stop the engine long before the proper speed had been obtained. The shaft was taken out, smoothed up, and the bearing carefully lapped out, to give more room for oil, and under an unusual lubrication, it again cut. A case-hardened iron shaft was tried with slightly different result. Steel was then used, and the same size steel shaft ran without cutting and showed, after long use, no unusual wear. The steel used was that known as machinery steel, and was adopted in place of iron only on account of its being stiffer. A careful examination of the conditions under which the soft iron and the case-hardened iron gave out, clearly indicated that the shaft bent in the journal under the pressure of the work on the crank.

In machine shop practice, iron shafts are used on account of their cheapness wherever practicable, but when it is deemed advisable not to increase the diameter, on account of the velocity, or for other rea-

sons, steel is always resorted to as permitting greater strains, so that in considering the proportions of machines, it is common usage, in case of doubt as to strength of shafts, to substitute steel for iron.

S.

The Commission on Water Supply, to which we referred in our last number, have devoted their time and attention ever since to the examination and study of the important matters entrusted to them. The survey for the conduit line from the proposed Perkiomen Reservoir, to the East Park Reservoir, has been made to a point on the Wissahickon, whence to the East Park Reservoir the topography having been previously obtained, the general character of the route is known. The distance on a final line would be about 34 miles, which is much longer than the distance originally contemplated. While the local obstacles along the route to the construction of this conduit line may not be more formidable than had been formerly anticipated, its increased length will of course add to its cost. The estimates of its cost we learn have not yet been completed.

The survey for the proposed conduit line from a point opposite New Hope, high enough to bring the water by gravity from a reservoir in that vicinity, to a convenient city distributing reservoir, has been begun, and is now in progress.

These surveys are made under the direction and supervision of members of the Commission. Measurements of the actual pumping at Fairmount Works have been made on several occasions by members of the commission, assisted by other experts; the results of which will appear in their report.

The subject of the pollution of rivers, by sewage, etc., and especially in its bearing upon the water supply from the Schuylkill and Delaware rivers, is receiving particular attention. A number of analyses of water from various points have already been made and reported, and others are still in process of investigation.

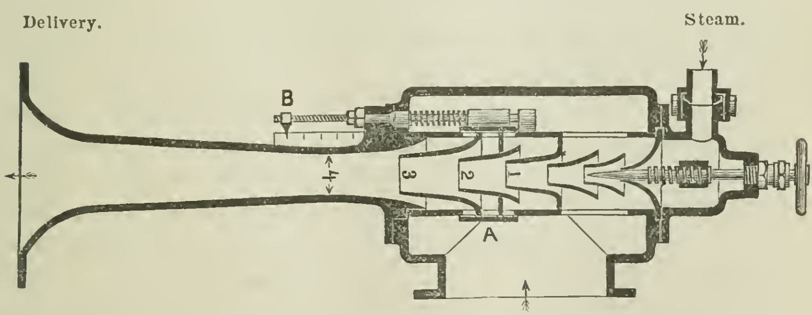
Purity is the first consideration; abundant supply, although of vast importance, must be secondary. There seems to be no question, however, that the City of Philadelphia has at her command, for the future, an ample supply of the purest water; but it is important to ascertain the best plan for introducing and maintaining it. It is to be presumed that the gentlemen having the matter in charge will overlook nothing that may be essential to a correct judgment upon a matter of such vital consequences to the City of Philadelphia.

Kœrting's Jet Apparatus.—The invention of M. Giffard's injector, and the success attending its introduction, suggested at once the application of its principles to other purposes. Out of it, besides a host of rival "injectors," have grown the "ejectors" and "ejector condensers" of various makers. Prominent among the workers in this field, appears the name of Mr. E. Kœrting, of Hanover, who has of late directed his attention to the utilization of induced currents as a means of transmitting motion and power; some of this gentleman's very successful applications of the steam jet are exceedingly interesting and well worth the careful attention of engineers. These various devices of Mr. Kœrting appear to supply a want long felt, and to have proved a paying investment for the inventor.

Our attention has recently been directed to this subject by Messrs. Schütte & Gœhring, of this city, who, we understand, are the licensees of Mr. Kœrting in this country, and who have made some modifications in his inventions, adapting them to American use. We have had an opportunity to see in operation one of Mr. Kœrting's "Forge Blowers." In this case a jet of steam of about $\frac{1}{32}$ of an inch in diameter puts in motion a column of air of, let us say, 10 lbs. pressure. This induced current of air, mixed with the steam which set it in motion and by which it was warmed, passes into and through the inducing nozzle of a second apparatus where it increases its volume by additional air. The volume of air discharged from the first blower and used as an inducing current in the second blower, is conveyed to it through a receptacle constructed as a cooler, in such a way that the air which is drawn in by the second blower is also made to pass through this receptacle, side by side with the mixture of air and steam, thus taking up some heat, condensing the steam, contained in the primary blast, and in this way forming a condenser and heat regenerator at the same time, so that the heat of the small amount of steam employed at first is used in warming the blast, while the blast is freed from moisture, which might be detrimental in obtaining welding heats. The apparatus we saw in use was placed in an establishment where a forge was needed, and which was not accessible to the blast pipes that supplied wind to the other forge fires. The exceeding convenience of this little blower operated by, seemingly, so small a quantity of steam, was very noteworthy. We understand the American licensees contemplate some change in the form of the "Jet Forge Blower," and we may at some future time illustrate it.

We now present a cut of Mr. Kœrting's "gas exhauster," for the purpose of keeping the pressure off of the retorts, or a slight pressure or vacuum on the retorts as may be required. This instrument illustrates the principle applied to all of the Kœrting devices for forcing or exhausting air or gas.

The inducing current in this case is a steam-jet, the quantity of which is controlled by a spindle in the steam nozzle; and the induced current is formed in a series of nozzles of increasing area. The purpose of these nozzles is to regulate the admission and proper mixture of the inducing and induced currents in such proportions as not to lose power by sudden shocks. In the particular use to which this instrument is applied, as in many other cases, the quantity of delivery must be variable, while all the other conditions remain the same. Thus, supposing the difference of gas consumption in winter and summer to be, say four to one, in each case the counter pressure of the washers, purifiers, etc., remains the same. To overcome a certain pressure, the induced current must have a certain speed, depending on the specific gravity of the liquid or fluid, so that to reduce the quantity of delivery working against the same pressure, the size of the instrument must be reduced, *i. e.*, the area of the last mixing nozzle must be reduced. This is accomplished in the following manner:



The inlets to the last three mixing nozzles are closed by a slide, A, so that in the positions of the slide, as shown in the cut, the last admission of gas is through nozzle 1, which in this case, constitutes the size of the instrument, and the gas admitted up to 1 is from there discharged through the remaining nozzles, the same as if they were a continuation of the diverging tube. By forcing the slide towards

the delivery end of the instrument so as to admit gas successively through 2, 3, and 4 by uncovering the inlets into these nozzles, the capacity can be increased correspondingly to the areas of their nozzles, all other conditions remaining the same, except a proportionate increase or decrease of steam admission by means of the spindle in the inducing steam nozzle. From experiments we have seen tried, great care is needed to have these various parts correctly proportioned, but when so proportioned the instrument is said to be economical, and to compare favorably with other efficient devices. It is claimed by the makers that the correct proportion is so imperative that instruments made of the same general size, but not correctly proportioned, have been found to require ten times the amount of steam for the accomplishment of the same purpose that a well-constructed apparatus needs.

Mr. Kœrting claims that for all purposes where a blast of air or other gas is needed, his instruments will be found economical and convenient; and that in producing and maintaining a vacuum, of say twenty-two inches of mercury, they have proved successful.

All jet apparatus work may be classed under the head of the mode of performing work by the continuous action of combined bulk and velocity. The principle has been quite fully illustrated in the various papers that have been written on the Giffard Injector for supplying steam boilers with water, so far as that instrument is concerned, and well-informed engineers are apt to speak of all kinds of jet apparatus as Giffard injectors. But a Giffard injector cannot be used to perform all the kinds of work to which the jet has been successfully applied in well-proportioned instruments. Thus, while the Giffard injector is admirably adapted to forcing water into a steam boiler, it presents a very uneconomical mode of merely lifting water into a tank. In each application of the jet of steam to perform work, the apparatus must of necessity be modified to suit the peculiar work required to be accomplished. The two examples given of the gas exhauster and the forge blower explain what we mean, in both Mr. Kœrting's arrangements of multiple nozzles, *i. e.*, of nozzles which take in the air or gas in succeeding spaces and succeeding nozzles, are used, but in one process there is no attempt to separate the steam from the gas, while in the other the steam is condensed, in inducing a second ingress of air, which enters the fire free from moisture. When the blowers, actuated by jets of steam, are used as under-grate blowers, the steam admitted with the air is a positive advantage, as the grate bars are

somewhat preserved, and the slight moisture seems to act advantageously on the fire which is required to yield its heat from the surface of the fire after the air has passed through it and combined with the burning fuel. In a forge-fire, or in a cupola, the heat is required to be used at the point where the air strikes the fuel and in the mass of the fuel—not from the surface of the fire. S.

Silver Coinage.—The Director of Mints, now on this coast busily preparing the mints in this city and Carson for an increased silver coinage, says, in a letter from Carson, dated July 16th: "The hydraulic presses and other machinery sent out here last year have been placed in position, and will do more than double the coinage capacity of the Carson mint, and it is estimated that with the necessary coinage of gold there can be coined half dollars and dimes. The supply of trade dollars will probably be sufficient until September 1st. In the meantime, I hope to be able to arrange for the coinage of divisionary silver coins at the two mints at San Francisco and Carson, at the rate of from $1,200,000 to $1,500,000 per month." It is estimated that the amount of fractional silver turned out from the coinage mints within the next six months will be at least $4,000,000.—*Mining and Scientific Press.*

Puddling with Natural Gas.—The following information regarding the use of natural gas in puddling iron at the works of Messrs. Rogers & Burchfield, Leechburg, is obtained from the *American Manufacturer*. These works, which have become so famous for the use of natural gas in the operations incident to rolling mill practice, are situated on the right bank of the Kiskiminitas, about six miles above its junction with the Allegheny River. There are five puddling furnaces, with two more building, six heating-furnaces, six trains of rolls, two steam-hammers, one refinery, two knobbling fires, two annealing-furnaces, and one "stack" for terne plates, and two building for tin-plates. All of the heat and power required for this mill is from gas, excepting, of course, the charcoal used. This gas comes from a well in a ravine on the opposite side of the river, which was sunk for oil, but produces only gas and a small portion of salt water.

* * * * * *

"In using the gas in the ordinary puddling-furnace, the only change made has been to brick up the bridge, the gas being fed to the fur-

nace through iron pipes, and the firing being done with a piece of lighted paper, the supply being regulated by an ordinary gate. The result is that the heat can be controlled at will without any more attention than the mere turning of a gate, and as fully a third of the labor at a puddling-furnace is keeping up the fire, this is no considerable item. * * * * * *

"The pipes conveying the blast are carried in at the top of the furnace, and strike the molten metal at an angle with the surface of somewhat over 90°. During the week, up to Friday noon, less than 500 pounds of ore had been used in feeding the furnace. No cinder was used when the iron began to boil, but the blast was put on, and the boiling was complete, the cinder in the iron flowing liquid. * * * * *

"The quality of the iron is somewhat wonderful. With the ordinary gray coke iron, sheets for tin-plates, equal to those from the best charcoal iron, are made at a cost of $50 per ton less. The knobbling fires are dispensed with, and all their iron made with the use of gas and blast. In a future issue we expect to give the results of some careful experiments."

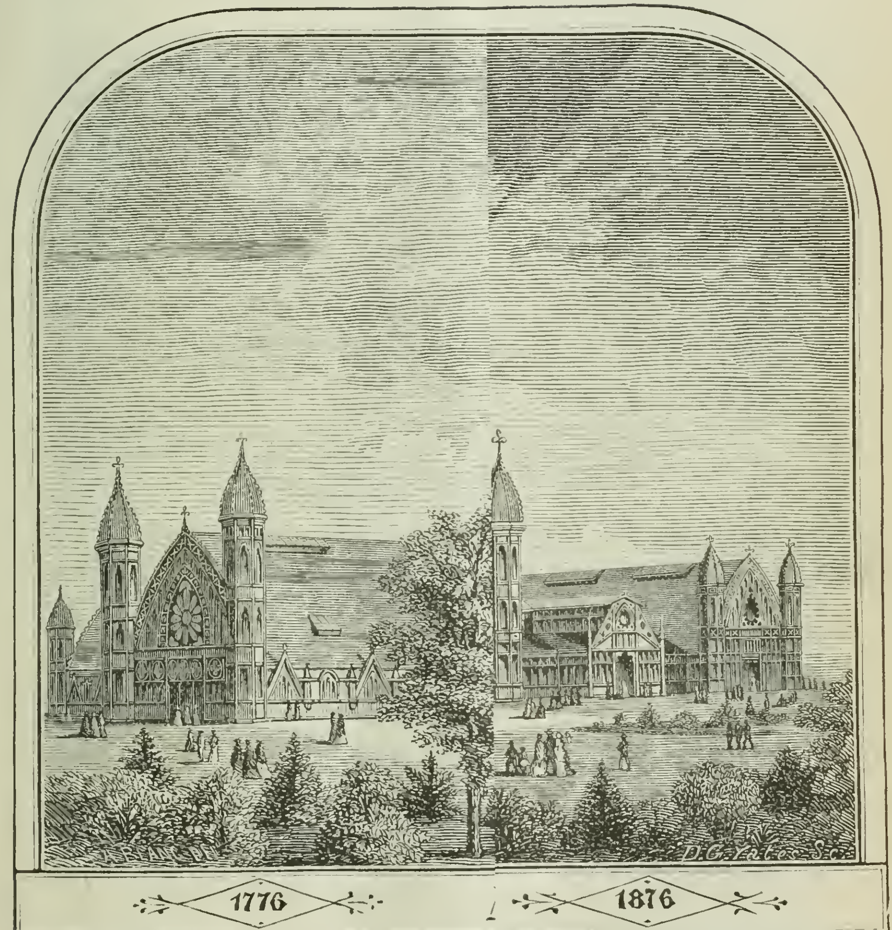
Centennial Exhibition.—The next in importance, after those already illustrated, is the Agricultural Building, which will stand north of Horticultural Hall, and east of Belmont Avenue.

The extreme dimensions of the building are 540 feet front by 800 feet in depth, consisting of a central nave 800 feet in depth by 100 feet in width, with a central transept 100 feet in width by 540 feet in depth, and two side transepts 80 feet in width by 540 feet in depth.

The construction of the nave and transept section is by Howe trusses, built curvilinear, and set to the form of two sides of an equilateral Gothic arch, springing from the ground line.

The principals are set to uniform spacings of 20 feet between centres, the depth of truss being 4 feet 6 inches for the 100 feet spans, and 3 feet 9 inches for the 80 feet spans.

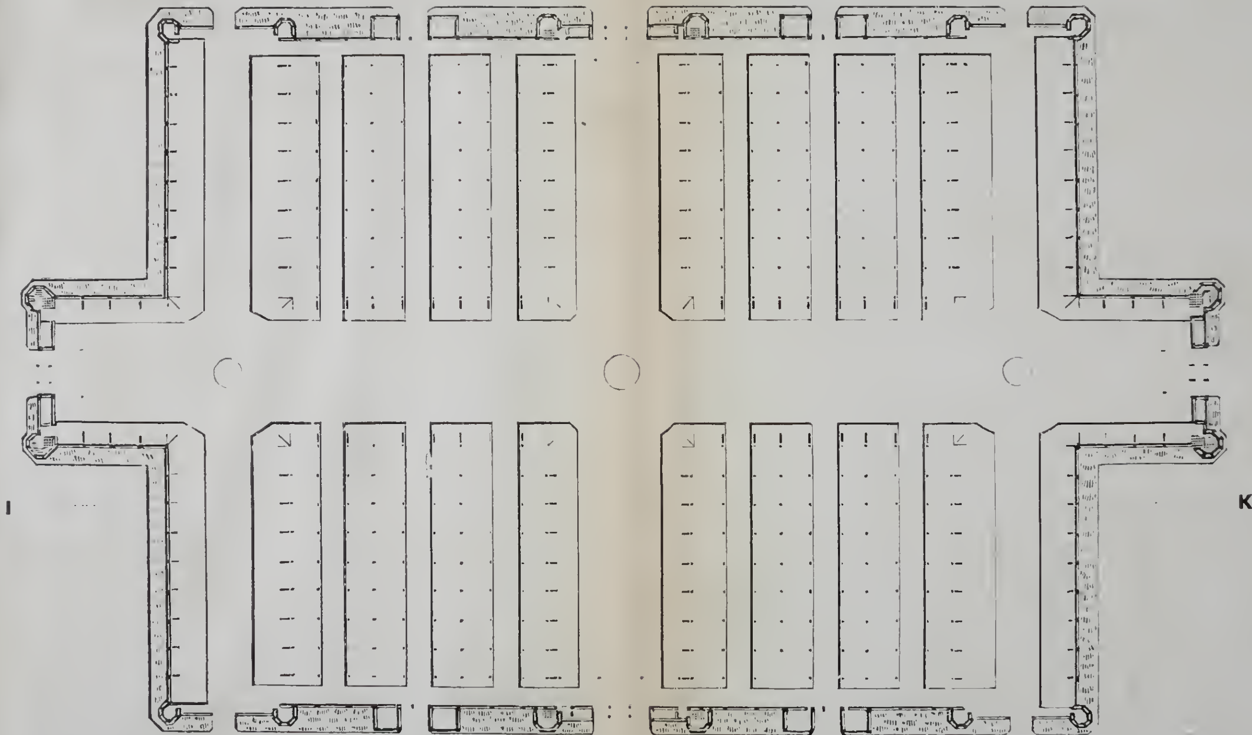
At the intersection of the nave and central transept, the diagonal trusses are coupled, separated 8 feet by lattice bracing, at the foot being 10 feet in depth, converging to 6 feet at the base of dome and lantern. The intersection of lesser transepts with nave are propor-



Inter.

AGRICULTURAL BUILDING.

International Exhibition, Philadelphia, 1876.



Ground Plan of the Agricultural Building.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.

tionately less, but of similar construction. The intervening areas between the nave and transept sections are enclosed by simple shedding.

The entire structure will be built of timber left from the saw, to be finished upon interior surfaces by an alum sized color wash, only the exterior siding and frontal lines being planed for painting. The section of building formed by the arch trusses will receive light direct by glass sections, in planes forming roof cover, their stilt at the base constructed, as Louvres, for ventilation. The intervening shedding will have lantern lights continuous their depth, in each bay of 60 feet.

The truss system adopted for the major portion of the building, provides roof and wall construction in the one element, a truss, enclosing the extended floor area in the simplest manner; while the elevation of the roof section and its form, converging to the ridge, will lessen the effect of the sun's heat, to which space, enclosed by temporary roof cover, without the protection of a ceiling beneath, is subject in the summer season.

The object of this structure being to provide space for the display of agricultural machinery and products economically, simplicity of construction was sought, rather than embellishment of a finished structure. Within the Agricultural Hall will be steam power, and all necessary appliances for driving all such machinery as cotton gins, sugar presses, plantation mills, threshers, fanning mills, &c.

The building is drained by sewage beneath the floor, is amply provided with fire-plug stations within and without, and with gas for police surveillance.

The contract for the works was awarded to Mr. Philip Quigley, of Wilmington, Delaware, who engages to complete them prior to January 1st, 1876.

The arrangement of the ground plan shows four main avenues, one running north and south, 780 feet long by 70 feet wide, crossing which at right angles, is one at the centre of the building, 472 feet long by 60 feet wide, and one 25 feet distant from either end of the building, 472 feet long by 30 feet wide. The building is thus divided into four sections, each of which is subdivided by three aisles 18 feet wide, extending through it, and opening into the main north and south avenue at one end, and at the other end into side passages which extend along the east and west sides of the building.

The eastern half of the Main Exhibition Building has the roof on, is partly glazed, and much of the floor is laid. The western half of the frame is up, and the sheathing on the roof, and there still remains the frame of the transept to erect.

That portion of Machinery Hall east of the transept, including the tower, is completed, except a portion of the floor, and is painted and glazed. That west of the transept is erected, and most of the roof on, and the frame of the annex is up.

In the middle tower, at the east end of this building, will be placed an immense clock with two large dials, one showing outward, and the other inward, and twenty smaller dials will be placed along the length of the building inside, giving the correct time from the same machinery.

All the masonry of the Art Building is completed, except a portion of the two arcades; the roof is all on, and the figure on the top of the dome is in place.

The iron-work and masonry of Horticultural Hall are completed, and a portion of the roof on.

The foundations of the United States Government Exhibition Building are laid, and the work is making good progress. K.

Banked up for 217 Days.—The following letter from the Union Iron Works Company, of Cleveland, to the editor of the Pittsburgh *American Manufacturer*, shows remarkable success in an operation which, when long continued, is always a source of anxiety to the managers of blast furnaces.

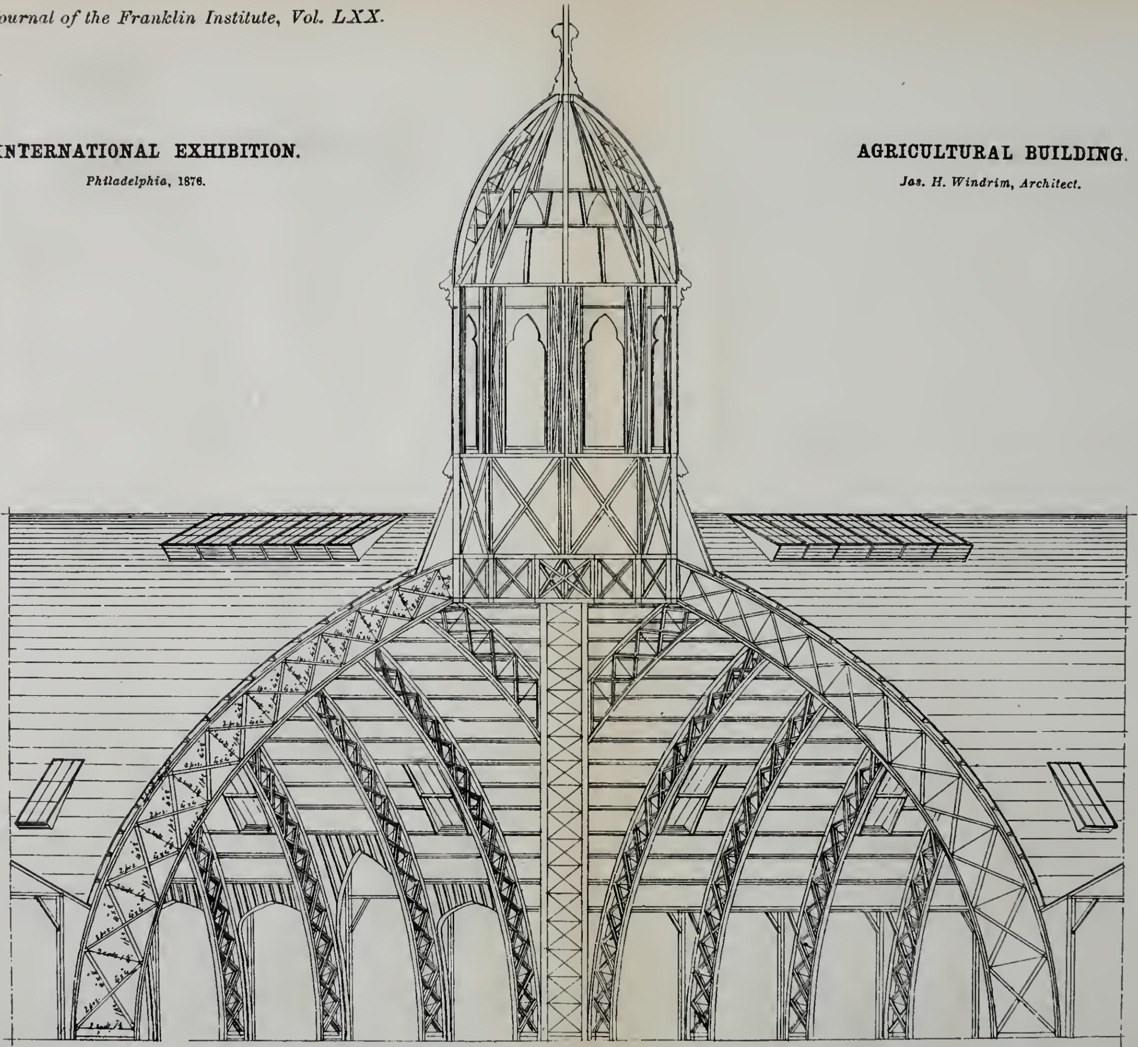
Editor American Manufacturer :—In your items of "Manufacturing News" of a few issues since we noticed some items regarding the blowing in of a blast furnace at Phœnixville, Pa, that had been banked up some 110 days, saying, "If successful it would be a remarkable feat," and a few items after that stating it was *not* successful. Permit us to call your attention to the following facts regarding the "Emma Furnace," owned and operated by this Company, which we think will be of interest to furnacemen and your readers generally. This furnace stood banked up from December 4, 1874, until the 9th inst. (July, 1875), being seven months and five days or equal to 217 days, without blast or draft, and this too during the most severe winter known for a long time. Standing this length of time holding her *fire* intact without chilling or cracking, or any unfavorable results, is, we think, a

INTERNATIONAL EXHIBITION.

Philadelphia, 1876.

AGRICULTURAL BUILDING.

Jas. H. Windrim, Architect.



ELEVATION OF MAIN DIAGONAL AT CROSSING OF 100 FT. TRANSEPT.

INTERNATIONAL EXHIBITION.

Philadelphia, 1876.

AGRICULTURAL BUILDING.

Jas. H. Windrim, Architect.

Section on Line IK.

very remarkable fact, and reflects very much to the credit and skill of those having her in charge.

The furnace, as stated, was banked or damped down December 4, 1874. The iron, etc., having all been run out she was filled wholly with Connellsville coke. Great care was taken in stopping her up, and every precaution known to furnacemen to have the *fire* remain until advisable to resume operations. We did not expect at the time, however, it would be necessary for her to remain idle more than two or three months at the furthest, but as the market presented no inducements to make iron, she was allowed to stand idle until July 9, 1875. During this *entire* time not a thing was done to her or a *pound of fuel added*. When opened at date given, two-thirds of the amount of coke put in was in good *live* condition, with *plenty of fuel* to commence with. After clearing away the accumulation of ashes from the bottom of the hearth, the tuyere irons were placed in position and blowing commenced, the furnace being ready to resume operations and in as good shape and condition as if only stopped for a few weeks.

The Emma Furnace is 65 feet high, 16 feet bosh, and 8 feet across at tuyeres. When stopped up was making 48 to 50 *gross tons* of iron daily, and is making the same at present, reducing Lake Superior ores with Brier Hill coal and Connellsville coke. Mr. Jas. Paton is General Superintendent, and Mr. Elias Metzler, furnaceman. We ask if this record has ever been equaled or excelled, and should be pleased to hear from you or your correspondents and readers through the columns of your valuable paper in reference to the subject.

Yours truly, S. A. SAGUE.

The Channel Tunnel.—We learn from the *Times*, (London) that at the recent half-yearly meeting of the Southeastern Railway, held under the presidency of Sir E. W. Watkins, M. P., that the following resolutions were proposed by the chairman and adopted:

"That the directors be authorized, if they should think fit, in accordance with the provisions of the Southeastern Railway Act, 1874, to apply any moneys under their control, not exceeding £20,000, towards the cost of any soundings, and of any borings, shafts, driftways, or other works in connection with the construction of the tunnel under the English Channel."

Pressure Gauge to Register Fifty-four Thousand Pounds.—We have been shown one of Shaw's mercury-column pressure gauges (illustrated and described on page 153, vol. lxvii, of the JOURNAL,) just completed for a company in this city to register fifty-four thousand pounds per square inch. The body of this gauge was forged solid from the best Midvale steel, and bored and turned to the proper shape. The total height is six feet, and the mercury column being four and a half feet. The area of the large plunges is eight and one-half inches and the small one is three-sixteenths, and the movement about one-thousandth of an inch. This is no doubt the highest range of pressures for which a gauge has ever been built.

Bibliographical Notices.

A CENTURY AFTER: PICTURESQUE GLIMPSES OF PHILADELPHIA AND PENNSYLVANIA. Published by Allen, Lane & Scott, and J. W. Lauderbach, Philadelphia, 1875.—This beautiful work is being published in fifteen semi-monthly parts, three of which we have already received, and these well sustain the promise at the commencement that the work would illustrate this city and state with all the resources of art. The subject is well portrayed by pen and pencil; the work is rich in representations of scenery and buildings of historic interest, relieved by occasional figure pictures of life and character. The designs are made by a number of our best artists and are engraved on wood in the most spirited and artistic manner, by Mr. J. W. Lauderbach, who stands at the head of his profession in this city, and is second to none in the country, in the beauty and fine quality of his engravings.

The literary conduct of the work is in the charge of Edward Strahan, and the good taste evinced is in harmony with the general fine character of the work. Much of the progress of the art of engraving on wood is due to the great improvement in typographic printing in late years; there has been little encouragement to the artistic engraver to show the capacity of his art, as without good printing, the best engraving is sacrificed. "A Century After" is most beautifully printed on fine toned paper, and thus the fine qualities of the illustrations are well presented. We hope the work will be well sustained by the public, as no worthier publication of its class has been presented for patronage.

Civil and Mechanical Engineering.

DESCRIPTION OF THE PERNOT FURNACE.

Translated from the French of M. Armengaud.

By William F. Durfee, Engineer.

Description of a Furnace with an inclined rotating bottom for the Puddling of Iron and the manufacture of Puddled Steel; invented by M. Charles Pernot, Engineer and Superintendent of the works of Petin, Gaudet & Co., at St. Chamond.

During a professional journey, we had the good fortune to see an apparatus which at once commanded our particular attention. We speak of the furnace with movable inclined bottom of M. Pernot, which we saw in operation quite recently at the establishment of MM. Petin & Gaudet, at St. Chamond. We were so much impressed with the results of this ingenious apparatus, which are established beyond doubt, that we think this communication to our readers (which is entirely reliable) will be received with great interest.

The first of these furnaces (the one originally erected, and which was for a long time the subject of the most serious study by its inventor) is used for the mechanical puddling of iron, an operation both delicate and difficult, and one which has occupied the attention of many persons in recent years.

The second furnace is intended for the manufacture of puddled steel, and is destined to replace with advantage various inventions more or less complicated and expensive, designed for the same purpose. These, therefore, seem two important inventions which may introduce great changes in the metallurgy of iron and steel, as they have the double merit of simplifying the hand-work and giving many other economical results without necessitating material changes in works already erected.

We have explained in a preceding volume the general character of "The Danks'" system, and also described the modifications it has received in the rotating furnace of Mr. Wm. Sellers; we have also mentioned that M. Siemens has made a valuable contribution to it by his invention of the regenerative gas furnace. It is not necessary to the purpose of this description to note the advantages or disadvantages of the puddling furnace of M. Danks, but we will briefly describe his process, which by its novel character and the boldness of its conception has greatly excited the public curiosity. For this purpose we think we cannot do better than to reproduce the notes of M. Jules Petin, Jr., mining engineer, who also visited England for the purpose of investigating this new invention. "We think," says M. Petin, "that the greatest economy of the process of M. Danks arises from the great quantity of iron which can be treated at a single operation." Not only can 661·42 lbs. (300 kilo's) be treated at one time by this means, but it is possible to operate on 1102·36 lbs. (500 kilo's) and upwards, as was stated by M. Danks, Jr. in the presence of MM. Pernot and J. Petin.

Although it is possible in the course of experimental working to produce a single "ball" of 650 to 1100 lbs., yet practically these masses are divided into several "balls." For working the larger "balls" special tools are necessary; the steam-hammer though of great power, is not convenient for this purpose and the manipulation of the "balls" by men alone is absolutely impossible.

"M. Danks invented and constructed a gigantic camb-squeezer with a hammer at the end, which squeezed and hammered at the same time. Notwithstanding its high cost, the employment of this instrument afforded a partial solution of the difficulty, but did not remove it. The "ball" after squeezing is not in a shape to be practically useful, its dimensions [39·37 in. (1 meter) long, by 11 to 15 in. (3 to 4 decimeters) in diameter] prevent its passing through rolls of ordinary size for conversion into bars unless reduced by the steam-hammer. It will undergo a considerable reduction of temperature by this work, and must then be reheated and divided by a "cutter" under a steam-hammer, otherwise it will be necessary to construct rolls of sufficient size to take the "bloom" directly from the squeezer. We may form from the foregoing some idea of the expense necessary for changing a works from the old method of puddling to the new system of Danks.

"The following is a list of the principal apparatus used in the establishment of Erymus, at Stockton, (England), for twelve Danks' furnaces: 2 cupolas on the Thomas' system; 12 Danks' furnaces; 2 reheating furnaces; 2 12-ton shingling hammers; 2 sets heavy rolls; 1 Danks' squeezer; 4 auxiliary steam boilers, the steam produced by the waste heat not being sufficient to work the rolls.

"For a new works the relative expense will be considerably increased, and in reconstructing works already established, the almost total loss of the old material augments enormously the cost of the introduction of the new system."

It must be remembered that the principle of rotation applied to puddling furnaces has been public property for many years in France as well as in adjoining countries, since the first patents taken out for this object are dated in 1853. Be it as it may, of all the systems that have been proposed up to the present time, we believe that of M. Danks to be best known, particularly in the United States, as having given relatively the best results. However, we do not think it will progress with the same rapidity and ease with ourselves as with others for the reasons already given, especially in the presence of the Pernot furnace whose simplicity and economy are so very remarkable.

Principles of the Pernot Process.—Applied to the Mechanical Puddling of Iron.

The process invented by M. Pernot but distantly resembles the foregoing, as we shall see. He takes an ordinary puddling furnace and makes the bottom independent, it is in fact a kind of great circular basin which is inclined so as to be but partially covered with the bath of molten iron. This basin, which the workmen call the "pot," is mounted on an oblique axle, and receives a rotary movement which constantly displaces the fused metal. At its junction with the fixed part of the furnace there is an allowance for play of from 1 to 1½ inches (3 to 4 centimeters).

The ash-pit is tightly closed and into it the blast is introduced, which when operating causes the flame and the gas which fill the furnace to pass over the movable bottom without escaping at the joint which exists between it and the fixed parts, and without allowing the penetration of the exterior air, for the equilibrium of pressure of the air and the gaseous products of combustion is an essential condition, and

is an advantage which renders the process completely practical by reducing the repairs of the joint which is reasonably durable. A continuous stream of cold water is projected during the operation upon the outside of the "pot," which is thus cooled and maintained in a perfect state of preservation.

We know that in the ordinary furnaces with fixed bottoms, they have the same cast iron bed which is exposed to the action of the cinder and flame, and that the parts forming the inside of the bottom do not suffer from their action, but part with the same degree of heat they receive. It is the same with the inclined movable "pot," all the molecules of the metal are successively exposed in thin layers for a short time and are carried round and elevated by the rotation, into the upper part of the furnace, and yet they are not unduly exposed to oxidation because as they arise they again descend and are plunged in the bath of iron which is in the lower part of the furnace.

"The following conditions," says M. Petin in his paper, read before the French Society of Civil Engineers, and the Iron and Steel Institute at London, "exist in the mass from various causes during the progress of the heat:

"1st. The temperature produced by the heat of the fire urged by the blast is very regular.

"2d. Each part of the bath is heated successively in thin layers as we have before stated, instead of being heated by the surface alone, as in ordinary furnaces.

"3d. The heat arising from the chemical re-actions produces an intermolecular combustion which has been compared by M. Jordan to some of the phenomena of the Bessemer process, and which is manifested in the most energetic manner."

The whole movable apparatus is mounted on a four-wheeled car, which permits its being easily withdrawn from the furnace which it is necessary to do in order to facilitate repairs, and this mechanical combination presents the advantage of not losing the time which in other furnaces attends their complete cooling in order to allow of the repairs which are required after one or more operations. Farther on we will give the results obtained in recent experiments with irons of various kinds in this furnace, which appear to us valuable; of these results we will give an exact account, which will show the progress already made.

Description of the Pernot Puddling Furnace.—Represented by the Accompanying Figures.

Fig. 1 is a longitudinal section taken through the axis of the furnace, along the line 1–2 of the plan, (Fig. 2.) Fig. 2 is a horizontal section, taken at the height of the line 3–4–5, and passing above the movable bottom, as is seen on the plan. Fig. 3 is a transverse section passing through the axis of the movable "pot," along the line 6–7, (Fig. 2.) Fig. 4 represents an exterior elevation of the "pot" and its carriage withdrawn from the fixed part of the furnace. Fig. 5 shows the under side of the "pot." Fig. 6 is a section of the furnace along the line 8–9, and shows from above, the carriage on which the "pot" turns when in use.

All these figures are drawn to a scale and represent an apparatus sufficiently large for the treatment of from 2200 to 2600 lbs. (1000 to 1200 kilogrammes) of metal at a time, and for the making of eight charges in twenty-four hours, which will correspond to a product of from eight to nine tons. As will be seen, the apparatus is composed of two distinct parts, the one fixed and the other movable. The first nearly resembles, in general appearance, an ordinary puddling furnace, with the exception of the lateral sides A and A′, (Fig. 2), which are considerably swollen in the middle instead of being the prolongation of the side wall of the fire-box B.

The roof, C, also presents in the elevations and vertical sections a great similarity to the old form of furnace with a fixed bottom, particularly over the grate and at the flue which conducts the smoke to the chimney. But the central part is circular, as may be seen in the horizontal section Fig. 2, and corresponds in diameter to that of the movable bottom, and is exactly the shape of the edge of the "pot." From 1 to 1½ inches (3 to 4 centimeters) above the circumference of the upper edge of the "pot" is placed a ring of cast iron, *a*, at the same inclination as that of the bottom of which in fact it is an extension, it is supported by massive masonry and serves to receive and sustain the fire-brick portion of the furnace. In front of the furnace are placed the two working doors D, through which are introduced the materials to be treated, and which are entirely closed during the early part of the operation, but are opened when the metal has arrived at a state of fusion and "rabbling" is required, finally the

separation of the metal is effected and the several "balls" are successively taken out, which is rendered very easy by the "pot" being made to change its place.

The fire-box, B, is completely closed during the working, and the fire is urged by a blast supplied by a fan blower, by means of a pipe whose outlet is at *b*. The "stoke-holes," *c*, through which is introduced the fuel, are stopped with fine coal without difficulty. The "sight holes," *d*, are arranged in the end of the furnace in order to allow an examination of the interior when necessary; and are firmly closed by a plate of cast iron, *d'*. The ash-pit is likewise tightly closed by means of two hinged doors of plate iron, E, in order that the blast may be forced through the grate.

As in ordinary furnaces, the whole of the exterior of the body of the furnace is composed of plates of cast iron, F, adjoining one another, these are retained in position by the rails, G, which replace with advantage the square bars and angle-irons commonly used. The second part of the apparatus, that which is a substitute for a fixed "bottom," properly so called, consists principally of a large tub, H, (called by the workmen the "pot") whose interior surface is formed by a lining of ore which is placed on a bottom plate, I, of plate iron, and against a cylindrical envelope composed of numerous plates of cast iron bolted and keyed together, forming a rim, J. These plates, which can be removed and replaced with ease, are pierced with holes so that they can be penetrated by jets of water which are carried around the envelope and serve to keep the lining continually cold, notwithstanding the high temperature of the furnace. Beneath the bottom plate, I, is placed a bevel wheel, K, which gears with the bevel pinion, L, by which the "pot" is given a rotary movement of two or three turns per minute.

The axis of this pinion is prolonged, (as may be seen in Fig. 2) and carries at its other extremity the bevel wheel, M, which by means of the small pinion, N, receives the power of a double cylinder steam engine coupled to the shaft of pinion N by cranks at right angles, thus avoiding dead points and the employment of a fly-wheel. Four conical rollers, P, are placed beneath the bottom of the "pot" and which roll on the circular track, Q, which instead of being horizontal, presents on the contrary an inclined plane, which obliges the whole of the movable bottom to have the same inclination while revolving and thus in proportion as it turns it constantly displaces, as

we have before said, the fused materials which are consequently most rapidly and regularly heated. The axles of the rollers are held in bearings of cast iron, fitted and bolted beneath the bottom plate I. The whole of this machinery is skillfully combined to give the apparatus the firmness and solidity desirable and to insure a rotary movement of perfect regularity, without shock or noise, and which is easily controlled, notwithstanding the weight of materials which it contains, and the high temperature of the furnace.

The circular track, Q, forms a part of a four-wheeled carriage, R, which runs on two parallel rails, S, which serve to introduce the apparatus into the interior of the furnace, as is shown in Figs. 1, 2 and 3, and for withdrawing it as is seen in Fig. 4. This arrangement is most important, as it allows necessary repairs to be immediately made, without loss of time, whereas in the old-fashioned form of furnace it is essential that it should stand without firing fifteen or twenty hours before it is sufficiently cool to allow the workmen to enter it.

The furnace which we have described, and which is in daily use at the works of St. Chamond, has a movable "pot" of a mean diameter of 94½ inches (2·40 m.) which corresponds to a surface of 48·7 square feet (4·522 m.), and it is able to treat one ton of metal per charge although its relative depth is very small.

In the first furnace tried by M. Pernot, and which was erected at the works of Petin & Gaudet, these dimensions were much smaller and only sufficient for the treatment of from 661·2 lbs. to 1000 lbs. (300 to 400 kilo's) per charge.

With the present apparatus from four to five charges per turn of twelve hours can be worked without difficulty, drawing seventeen or eighteen "balls" or "loops" at each, the last being as hot as the first. The continuous rotation of the bottom enables the workmen to divide the "balls" with ease, by bringing all parts of the fused metal successively before the working doors, and this rotation also enables the removal of the balls when formed to be accomplished without difficulty.

Preparation and Management of the Apparatus.—Preparatory Operations.

After drying a new furnace and raising it to a white heat, we oxidize some "scrap" in the same way as in the ordinary system of puddling, for filling all the joints formed by the pieces of iron ore which are

placed around the sides of the furnace, and finally we have a united smooth surface without fissures. As soon as the "scrap" becomes hot, we shut off the blast to oxidize and make it flow, this is quite necessary in furnaces that are worked with a blast, as the flame repels the air and will not permit it to enter the doors.

During all the time required for heating and oxidizing the "scrap," which is about one hour, the bottom remains fixed, or is allowed a movement of but two or three turns per minute, which corresponds to a circumferential speed of from 1 to $1\frac{1}{2}$ inches (25 to 40 centimeters) per second. As a result of the rotation, the liquid oxide of iron covers the entire bottom, and the puddler covers the sides of the "pot" with the aid of a tool called a bottom-paddle.

The movement imparted to the apparatus renders the operation of preparing a lining a very easy one, and the streams of water which are conveyed to the exterior envelope, as we have seen, prevent the sides from getting hot, and at the same time cool the bottom, and these jets produce a real economy in the expense of repairs of the furnace. The bottom being prepared in the manner described, its cooling finished, and its hardening complete, the grate is then cleaned and the furnace is ready to receive its "charge." The bottom is repaired by burning or oxidizing more "scrap" whenever it is thought to be too thin.

Charging and Managing the Furnace.

We will now proceed to follow the treatment of a charge of one ton (1000 kilo's), of for example the white mottled charcoal iron of Toga, which we often saw used at the works of St. Chamond. After having introduced into the apparatus the hammer slag, or scales, from the rolling mill, and spread them properly in the usual manner, we charge the required quantity of pig-iron, which has already been heated in a special furnace of sufficient size to supply all the puddling furnaces in the mill, next we turn the blast under the grate, the "pot" remaining stationary; nevertheless if its exterior envelope begins to get red hot, we throw the jets of water upon it, at the same time giving it a few turns. The charge is soon raised to a bright red heat and then begins to melt and in about thirty-five or forty minutes it is completely fused.

It is at this moment that the operation of "rabbling," properly so called, really commences. We know that in the fixed furnaces this

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Fig. 1.

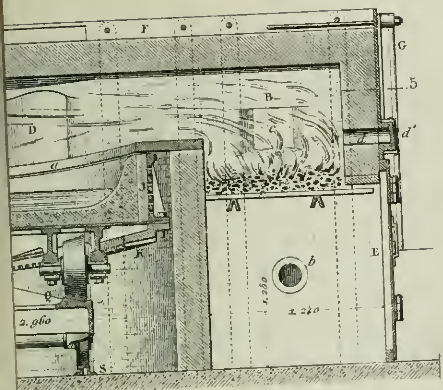
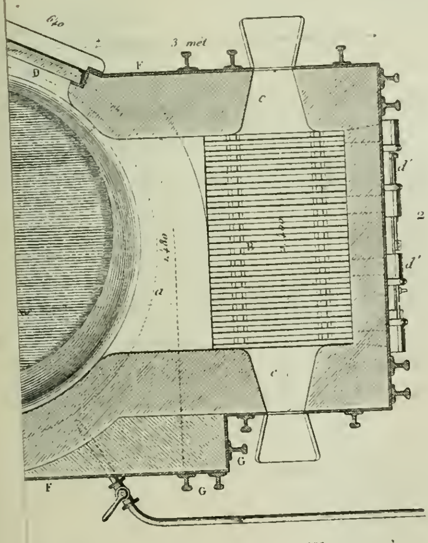


Fig. 2.



Pernot Furnace for treating 1 to 1¼ Tons of Metal per charge. and 8 or 9 charges per 24 hours

Fig. 3.

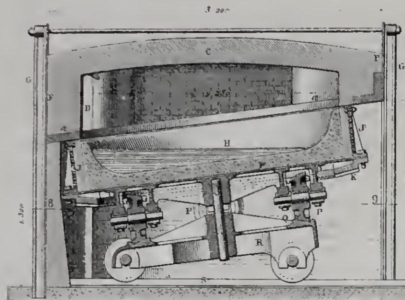


Fig. 4.

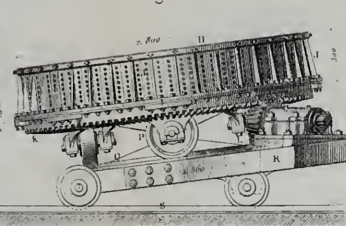


Fig. 1

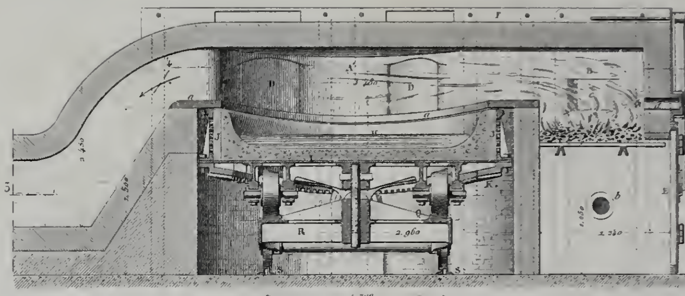


Fig. 6.

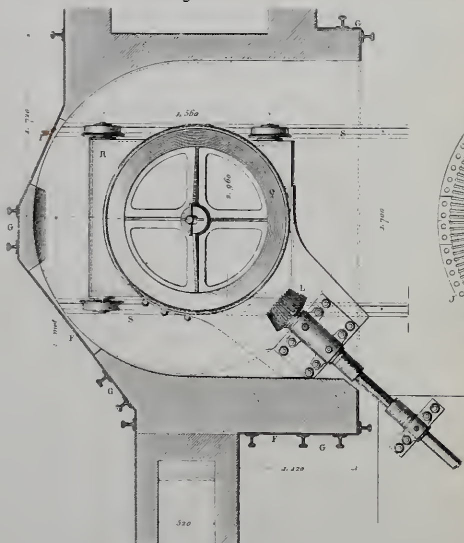


Fig. 5.

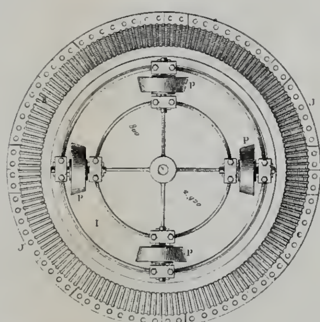
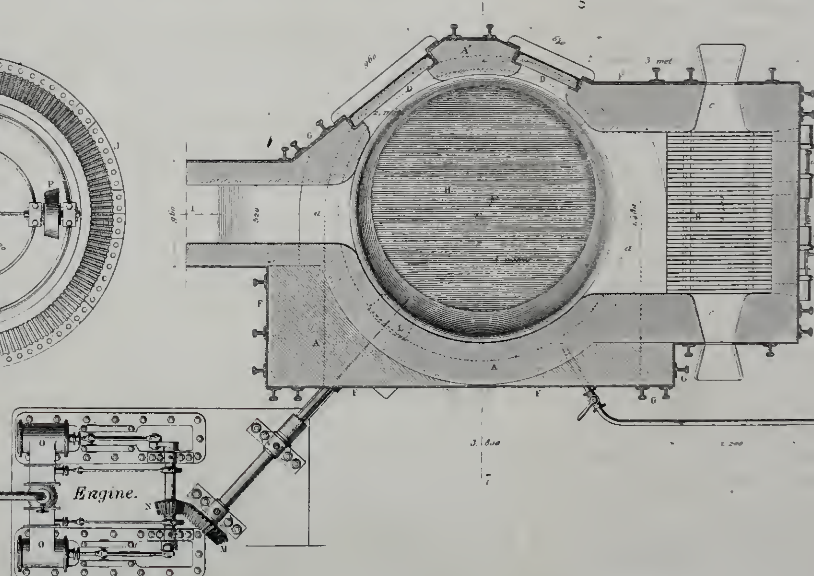


Fig. 2



Imp. Ch. Chardon aîné à Paris

operation is performed by hand, and by the skill of the workman, and is necessarily very expensive, but in the Pernot furnace the mixing and "rabbling" are effected without hand labor, by the rotation of the "pot," which is accomplished in the manner previously described. The damper applied to the top of the chimney is manœuvred from time to time by the puddler to suit the different conditions of the work, which are ascertained by testing the bath with a "peel," which is introduced through one of the working doors.

At the commencement of the operation, and principally with grey irons which require considerable time to melt thoroughly, we keep the damper nearly closed. We hasten this first period by throwing on the exposed parts of the bottom jets of water, which harden it as fast as it emerges from the liquid mass.

This practice has the additional advantages of protecting the "pot," and greatly reducing the expense of repairs. For the charge named, the thickening commences by the end of a quarter of an hour, or thereabout, and we gradually raise the damper in order to obtain all the draft and heat possible. At this time the bath has swollen to its greatest bulk. The boiling continues during ten or twelve minutes, and the bath then commences to diminish in volume, and the iron to "come to nature;" the "pot" has been kept turning all this time. The puddler is careful to aid the operation with his "rabble," which is easily done in this furnace, notwithstanding the mass of material; for by placing the rabble firmly in the door and supported against it, the agglomerations of iron become separated as fast as they form. We now cease turning and work the metal until it is so condensed that the cinder is completely separated, and it is ready to be gathered into "balls," this period occupies from twenty to twenty-five minutes. The puddler now proceeds to divide the mass, and to make it into "balls;" and will take out the first in about ten minutes.

The laborious work of "balling" is facilitated to the puddler, as we have before said, by the fact that it is always done in front of the working doors, by allowing the "pot" to make the necessary movement, without his being obliged to collect the iron which he finds on the right and left hand and pull it before him.

The "balls," in order to be handled without difficulty at the steam-hammer and the rolls, are generally of the weight of from 120 to 130 pounds (55 to 60 kilo's), and from the charge of one ton there is in fact produced seventeen or eighteen balls, which are obtained in about an

hour, and the bars rolled from them are remarkably clean and exempt from cracks. Finally the duration of the complete operation is less than three hours, which includes the time lost in charging another heat which allows from eight to ten charges per twenty-four hours. When "refined" iron is treated, a single furnace produces eight or nine tons of iron per day, and two thousand five hundred (2500) to two thousand seven hundred (2700) tons per year.

Results of Experience.

MM. Petin & Gaudet have very properly required us to communicate the results of the various trials which they have made at the furnace of M. Pernot since it commenced working. We think them particularly interesting as they furnish the proof that this system has arrived at a state entirely practical, and that it is called to render great service in metallurgical establishments.

Works at Saint Chamond.

At the outset in the first table (which is taken from the manufacturing books of the forge at St. Chamond) we have an exhibit of the economic results of the puddling of two hundred and ninety tons of refined pig-iron, and fifty tons of common pig-iron.

Materials charged in the furnace.		Weight and Kind of Iron Puddled.	
		Refined pig.	Common pig.
Charged for the production of 2240 lbs. of puddled bar.	Pig Iron, . .	2288 lbs.	2378 lbs.
	Coal, . . .	2863 "	1603 "

Upon examining this table we find the following results:

1st. The loss in puddling refined iron is forty-eight pounds per ton of bars produced, while it is as much as one hundred and thirty-two, and sometimes one hundred and fifty-four pounds in the old form of puddling furnace.

2d. The loss in puddling common pig iron is one hundred and thirty-eight pounds per ton of bars, instead of from 265 lbs. to 352 lbs., as is common in the old system.

We notice also a great difference in the consumption of fuel. Thus for refined iron, 2863 lbs. are burned instead of 3902 lbs., which is commonly used, a saving of 1039 pounds at least, and for "common pig," the consumption is 1603 lbs., when it was 2579 lbs. in the old puddling furnace, which shows an economy of 976 lbs. of coal per ton of iron.

The net cost (also taken from the manufacturing books of these works) compared with that of the old system, shows a difference of about $9.50 per ton of finished iron, an advantage of the new process, of which we will be convinced by the following comparative details.

Puddling by the Pernot Furnace.—Manufacture of finished iron, (February, 1874.)

Days' Work of Furnace		Consumption. Coal.	Pig Iron.	Wrought Scrap.	Roll Scales and Iron Ore.	Production.	Charged to produce 2240 lbs. Coal.	Pig Iron.	Wrought Scrap.	Roll Scale and Iron Ore.
27	2½	Lbs. 236,235	Lbs. 207,129	"	Lbs. 10,154	Lbs. 199,900 or 89·24 Tons.	Lbs. 2,650	Lbs. 2,321	"	Lbs. 105

Average product of the furnace per day, 7404 lbs.

EXPENSES.

			Net cost per ton of finished bar.
178,184 lbs. = 79·54 tons of Toga Iron, E.R.,	@ $36.51 =	$2,904.00	
25,902 lbs. = 11·56 tons of Toga Iron, S.L.R.,	@ 36.52 =	422.17	
1,764 lbs. = 0·787 tons of Toga Iron, E.S.R.L.,	@ 36.52 =	28.74	
1,279 lbs. = 0·57 tons of Toga Iron, B. E.,	@ 38.50 =	21.95	
207,129 = 92·457	Average price, $36.522 =	$3,376.86	$37.842
6,615 = 2·95 tons of Roll Scales,	@ $4.11 =	$12.12	
3,539 = 1·58 tons of Mokta Ore,	@ 6.98 =	11.02	
10,154 = 4·53 tons.		23.14	.25
236,235 = 105·46 tons of Coal,	@ $3.42 =	$360.67	4.04
Labor,		241.46	2.75
Cost of repairs,		181.86	2.03
General costs of manufacture,		52.07	.58
Other items of cost,		56.74	.63
		$892.80	
	Total,	$4,292.80	$48.12

Note—The quantities in this and the following tables have been made to conform to the ton of 2240 lbs. (1016 kil's) instead of that of 2204 lbs. (1000 kil's) as is the case in the original. W. F. D.

Puddling by the Old System.—Manufacture of finished iron, (February, 1874.)

Days' Work of Furnace		Consumption, Coal.	Consumption, Pig Iron.	Consumption, Wrought Scrap.	Consumption, Roll Scales and Iron Ore.	Production.	Charged to produce 2240 lbs. Coal.	Charged to produce 2240 lbs. Pig Iron.	Charged to produce 2240 lbs. Wrought Scrap.	Charged to produce 2240 lbs. Roll Scale and Iron Ore.
259	5	Lbs. 1,098,002	Lbs. 673,451	Lbs. 46,827	Lbs. 22,996	613,213 or 273·8 Tons.	3,798	2,460	171	86

Average product of the furnace per day, 2,368 lbs.

EXPENSES.		Net cost per ton of finished bar.
204,812 lbs. = 90·43 tons, Gray Clavieres pig, @ $37.71 =	$3,410.12	
369,591 lbs. = 164·99 tons, Soft Toga pig, E. R., @ 36.51 =	6,022.79	
55,301 lbs. = 24·73 tons, Toga pig, E.S.L.R., @ 36.52 =	903.14	
11,797 lbs. = 5·26 tons, Toga pig, B.E., @ 38.50 =	202.51	
31,950 lbs. = 14·24 tons, Toga pig, M.S.L.R., @ 36.51 =	519.90	
673,451 lbs. = 300.65 Average price = $36.78 =	$11,058.46	$40.39
46,827 lbs. = 20·9 tons, Wrought scrap, @ $21.29 =	$444.96	
22,775 lbs. = 10·13 tons, Roll scale, @ 4.11 =	41.63	
220 lbs. = ·093 tons, St. Leon Mokla ore @ 6.98 =	.65	
69,822 lbs. = 31·123	$487.24	1.77
1,098,002 lbs. = 490·18 tons Coal, @ $3.42 =	$1,676.41	6.12
Labor,	1,544.69	5.64
Cost of repairs,	460.29	1.68
General costs of manufacture,	339.45	1.24
Other items of cost,	363.01	1.33
	4,383.85	
Total,	$15,929.55	$58.17

Horme Forges.

The trials which have been made in the Pernot furnace of the irons of the Horme Co., in the presence of M. Roche, engineer, and superintendent of the manufacture, have also all given satisfactory results as is seen from the record of a few of them contained in the following table.

The problem presented, was to produce puddled iron of ordinary quality (similar to that which is habitually made in these works) by the use, as fuel, of small semi-bituminous coal and coal dust mixed, in the proportion of one part small coal to five parts dust, the mixture weighing 54 lbs. per cubic foot. They have worked sometimes with pig iron alone and sometimes have added turnings of wrought iron, or iron ore. The work commenced on the 20th of April in furnace No. 2, and was continued without stopping during six consecutive days, until the 25th.

TRIAL OF IRON IN THE PERNOT FURNACE BY THE HORME CO.

A. D. 1874.	Days' Work of the Furnace.	Number of Charges.	Pig Iron used.	Turnings and Scrap.	Iron Ore added.	Hammer Slag or Roll Scales.	Consumption of Coal.	Product of Iron, Puddle bar.	Product of Iron, Scrap.
April.			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
20	1	5	11,025			661	7,087	10,186	
20	1	4	8,820	1,764		661	6,704	8,123	841
21	1	5	11,025			661	6,896	10,412	
21	1	4	8,820	1,764		661	6,704	8,330	778
22	1	4	8,820	1,764		661	6,704	8,364	748
22	1	5	11,025		1,565	1,102	7,087	10,293	
23	1	5	11,025			661	7,279	10,498	
23	1	5	11,025			882	6,896	10,498	
24	1	5	11,025	882	1,587	882	6,704	10,401	267
24	1	5	11,025			772	7,279	10,421	
25	1	5	11,025		1,709	772	6,704	10,455	
Totals	11	52	114,660 or 51·2 tons.	6,174 or 2·75 tons	4,861 or 2·17 tons.	8,376 or 3·74 tons.	76,044 or 33·94 tons	107,981 or 48·2 tons.	2,634 or 1·17 tons.

On examining the foregoing table, we find 11 days' work of 12 hours each, and 52 charges of pig iron weighing in the aggregate 51·2 tons, which produced (with the addition to a few of these charges of a small quantity of scrap or ore) 48·2 tons of puddled iron, and 1·17 tons of iron from the scrap; and we find a consumption of

33·94 tons of coal. If we add to this amount 1·79 tons, which were used for "lighting up" the furnace, we find that at the expense of 35·73 tons of fuel we have obtained 49·37 tons of iron. The mean production was 8·94 tons in 24 hours. To re-state the result, we have from a mean of 2378 lbs. of pig iron, 128 lbs. of scrap (wrought iron), and 101 lbs. of ore, obtained 2240 lbs. of puddled bar, and 54 lbs. of scrap bar, with a consumption of 1579 lbs. of coal not including that used for lighting up. Now for the net cost per ton, we have:

PUDDLING BY THE PERNOT FURNACE.

Pig iron,	2,378 lbs. = 1·061 tons, @ $24.21 =	$25.68	
Coal,	1,578 lbs. = 0·703 tons, @ 3.46 =	2.46	
Wrought scrap or turnings,	128 lbs. = 0·057 tons, @ 17.57 =	1.00	$29.77
Hammer-slag or scales,	174 lbs. = 0·078 tons, @ 4.12 =	0.32	
Iron ore,	101 lbs. = 0·045 tons, @ 6.98 =	0.31	
Deducting scrap bar,	54 lbs. = 0·024 tons, @ $26.95 =		0.65
			$29.12

There remains for cost of materials,		$29.12
Labor,	$3.35	
Cost of repairs,	1.18	$5.85
General costs of manufacture,	.60	
Other items of cost,	.72	
Total,		$34.97

Thus the net cost of puddling by the Pernot process is $34·97 per ton (2240 lbs.) of iron obtained, supposing that the labor and other expenses remain the same as in the old mode of puddling; which they certainly do not, since we have seen above that the work of the puddlers is greatly reduced, and the daily production of the furnace considerably augmented.

In order to show the relative economy realized by the employment of this system, we give the following figures which have been taken from the Horme Works, and cover the time between the 1st of July, 1873, and the 28th of February, 1874.

PUDDLING BY THE OLD PROCESS.

In 2992 days' work was manufactured 5026·66 tons of puddled bar, for which was used 5801·26 tons of pig iron, 95·1 tons of scrap, 129·62 tons of hammer-slag, and 5489·45 tons of coal. The average product per day was 1·67 tons or 3·34 tons in 24 hours, which is but 37 per cent. of the production of the Pernot furnace. To produce one ton (2240 lbs.) of puddled bar, there was used 1·154 tons (2584 lbs.) of pig iron, 1·092 tons (2446 lbs.) of coal, 0·019 ton (43 lbs.)

scrap, and 0·025 ton (56 lbs.) of hammer-slag. For the net cost per ton we have,

Pig iron,	2,584 lbs. = 1·154 tons, @ $24.21 =	$27.93	$32.23
Coal,	2,446 lbs. = 1·092 tons, @ 3.46 =	3.78	
Wrought scrap,	43 lbs. = 0·019 tons, @ 22.27 =	0.42	
Hammer-slag,	56 lbs. = 0·025 tons, @ 4.12 =	0.10	
Labor,		$3.35	$5.85
Cost of repairs,		1.18	
General costs of manufacture,		.60	
Other items of cost,		.72	
	Total,		$38.08

The difference of cost is at least $3.11 per ton in favor of the Pernot system. Now on the supposition that a furnace produces nine tons in 24 hours, and runs 290 days per year, there would result a profit over the use of the ordinary furnace of $8017.10 per annum. In presence of such results as this, the Horme Forge Co. have not hesitated to agree with M. Pernot for the use of his invention in their works.

TRIALS OF THE IRONS OF THE FRANCHE-COMTE FORGE CO., IN THE PERNOT FURNACE.

Date, 1874.	Days' Work of the Furnace.		Number of Charges.	Pig Iron used.	Iron Ore added.	Hammer-Slag or Roll Scales	Consumption of Coal.	Puddle bar obtained.
	Days	Hrs.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
May 30th.	1	0	5	9,922		661	7,087	9,655
June 1st.	0	9	3	5,954	1,543	496	5,746	5,685
June 1st.	0	3	1	1,984		165	1,916	1,984
June 2d.	1	0	4	7,938		662	7,662	7,713
June 2d.	1	0	5	9,923		441	7,470	9,497
June 3d.	1	0	4	7,938	1,544	661	7,662	7,453
June 3d.	1	0	4	7,938	1,632	882	7,854	7,888
June 4th.	1	0	4	7,938		662	8,237	7,900
June 4th.	0	8	3	5,964		441	4,597	5,890
Totals.	7	8	33	65,499 or 29·24 tons	4,719 or 2·1 tons.	5,111 or 2·27 tons	58,231 or 26 tons.	63,666 or 28·41 tons

(To be continued.)

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 40.]

Of the relative economic propelling efficiency of the screws.—The function of a screw being to apply to the propulsion of a vessel the power received by its shaft from the engine, and the power thus received being the net power developed by the engine, that is, the power which remains after deducting what is neccessary to work the engine *per se*, it is evident that the economic propelling efficiency of a screw will be represented by the per centum of the net power developed by the engine, which is expended in the propulsion of the vessel. This per centum will be found on the last line (23) of the preceding tables, numbered from 1 to 6, both inclusive, containing the data and results of the experiments.

In the following table, No. 7, this per centum will be found expressed, relatively for the different screws at the different speeds of vessel from 5·0 to 8·5 geographical miles per hour.

Table No. 7, containing the relative economic propelling efficiency of screws, A, B, C, D, E, F, G, and H.

Relative economic propelling efficiency of screws,	Speed of the vessel per hour in geographical miles of 6,086 feet.							
	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
In per centum of the net power applied to the screw-shaft.								
A, E, and F	79·81	79·09	78·73	78·47	78·23	77·12	75·41	74·05
B	80·71	79·99	79·55	79·20	78·74	77·43	75·55	74·05
C	79·96	79·14	78·59	78·08	77·41	75·72	73·52	71·82
D	78·74	77·82	77·07	76·36	75·39	73·19	70 42	68·43
G	76·78	75 89	75 67	75·36	74·95	73·47	71·27	69·53
H	77·24	76·28	75·65	75·11	74·42	72·51	69·87	68·00
Relatively.								
A, E, and F	0·9888	0·9887	0·9897	0·9908	0·9935	0·9960	0·9981	1·0000
B	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
C	0·9907	0·9894	0·9879	0·9859	0·9831	0·9779	0·9731	0·9699
D	0·9756	0·9729	0·9688	0·9651	0·9574	0·9452	0·9321	0·9241
G	0·9513	0·9487	0·9512	0·9515	0·9519	0·9489	0·9433	0·9390
H	0·9570	0·9536	0·9510	0·9484	0·9451	0·9365	0·9248	0·9183

An examination of the immediately preceding table shows that, at all the experimental speeds, the propelling efficiency of screw B was the most economical, except in the single instance of screws A, E, and F, at the vessel's maximum speed of 8·5 geographical miles per hour, which gave an equal result.

The propelling efficiency of screws A, E, and F ranged from equality with that of screw B at the maximum speed of vessel to 1 per centum less economical at the minimum speed.

The screw C was less economically efficient than screw B by quantities ranging from 1 per centum at the minimum speed of vessel to 3 per centum at the maximum speed.

The screw D was less economically efficient than screw B by quantities ranging from 2½ per centum at the minimum speed of vessel to 7½ per centum at the maximum speed.

These results from screws A, E, and F, and screws B, C, and D, which only differed in that the three latter were composed of less fractions of the pitch than the three former, show that each diminution of this fraction below that of the screws A, E, and F, namely, 0·3570, was economically injurious, the loss of useful effect by the increase of slip consequent on this diminution being greater than the gain of useful effect by the friction of the screw's surface on the water, due to the same cause.

Screw G, composed of nearly the same fraction of pitch as screw B namely, 0·3446, and having the same diameter, had a pitch which differed in kind from that of screw B, and in quantity. It was both greater and, instead of being uniform, expanded continuously from the forward to the after edge of the blades. Screw G was less economically efficient than screw B by quantities ranging from 5 per centum at the minimum speed of vessel to 6 per centum at the maximum speed.

Screw H was the Griffith screw, formed from screw G by decreasing its surface at the centre and at the periphery. It was less economically efficient than screw B by quantities ranging from 4½ per centum at the minimum speed of vessel to 8 per centum at the maximum speed.

The foregoing relative economic propelling efficiencies of the different screws are for *smooth water with the vessel unaffected by wind.* The effect of a head wind being to increase the resistance of a vessel,

increases correspondingly the slips of the screws, and consequently changes their relative propelling efficiencies, thereby making those which gave the less propelling efficiency when unaffected by a head wind give a still less propelling efficiency when effected by it. In the case of an aft wind this result would be reversed. The trials of different screws in smooth water, with the vessel unaffected by wind, give their relative propelling efficiencies for those conditions only; but if those conditions be changed, these relative propelling efficiencies will change also. A really exhaustive series of experiments on screws would embrace the determination of their relative economic propelling efficiencies in smooth water with the vessel unaffected by wind, in smooth water with head wind and also with aft wind, in rough water with the vessel unaffected by wind, and in rough water with head wind and also with aft wind. Such a trial would show that the relative economic propelling efficiencies of screws of different types, dimensions, and proportions, applied to the same vessel, varied greatly with the varying conditions of wind and water, even to reversal in many cases, so that the screw which gave the highest result under one set of conditions might give the lowest under another.

Of the influence of different surfaces of screws otherwise the same, on the piston-pressure.—It is evident that, with the same engine and the same pitch of screw, abstraction being made of the friction of the screw-surface on the water, the net pressure on the piston of the engine must be the same at the same speed of vessel, let the surface of the screw and its slip be what it may. Accordingly, if we examine the remainder of the quantities on line 8, after deducting those on line 10, and for corresponding columns, in tables No. 1 to No. 4, both inclusive, containing the data and results of the experiments with screws A, E, and F, and B, C, and D, we shall find such to be the fact. The quantities on line 8 are the net pressures on the piston; that is to say, they are the pressures which remain after deducting from the mean gross-effective indicated pressure, (line 6,) the pressure (line 7) required to work the engine *per se.* The quantities on line 10 are the piston-pressures required for overcoming the cohesive resistance of the water by the screw-blades; or, as it is often termed for brevity, though incorrectly, for overcoming the friction of the screw-surface on the water. Making the comparison for the speed of vessel 8·5 geograph-

ical miles per hour, column h of the tables, we have the following results:

Screw.	Net pressure on the piston, (line 8,) in pounds per sq. inch.	Piston-pressure to overcome the friction of the screw surface on the water, (line 10,) in pounds per sq. inch.	Difference of the two preceding columns.	Slip of the screw in per centum of its speed.	Fraction used of the pitch of the screw.
A, E, and F.....	68·1537	3·9665	64·1872	14·57	0·3570
B.................	66·8945	2·8029	64·0916	16·15	0·2799
C.................	66·2274	2·2252	64·0022	19·43	0·1885
D.................	65·5689	1·3901	64·1788	24·24	0·1014

Of the influence of different pitches of screws, be their other dimensions what they may, on the piston-pressure.—With the same engine, it is also evident that, in the case of screws of different pitches, abstraction being made of the friction of the screw-surface on the water, the net pressure on the piston of the engine must, at the same speed of vessel, be in the direct ratio of the pitches, let the other dimensions of the screws, and their slips, be what they may; for the pitch measures the leverage at which the piston-pressure acts, and, when the speed of the vessel is the same, the slip cannot affect the problem, nor, consequently, can the dimensions of the screw other than the pitch, because their only function is to obtain a fulcrum from the water by embracing a sufficient quantity of that mobile substance.

This assumption can be tested by comparing the results from screws A to D, both inclusive, whose pitch is 5·136 feet, with those from screws G and H, whose pitches are 7 feet.

The net piston-pressure, less the pressure required to overcome the friction or the screw-surface on the water, is, for screws A to D, as above determined, 64·11495 pounds per square inch, which, increased in the ratio of 5·136 to 7·000, gives 87·3842 pounds per square inch of piston for the pressure with screw G. On referring to Table No. 5, line 8, column h, we find the quantity 94·4132; and, on line 10, same table and column, the quantity 6·8088; deducting the latter from the

former, we have 87·6044 pounds per square inch of piston, or almost exactly the same as obtained by the calculation from screws A to D, both inclusive.

Making the comparison for screw H in the same manner, we have 64·11495 pounds per square inch of piston with screws A to D, increased to (5·136 : 7 :: 64·1145 :) 87·3842 pounds with screw H. On referring to Table No. 6, line 8, column h, we find the quantity 92·5013; and, on line 10, same table and column, the quantity 5·0530; deducting the latter from the former, we have 87·4483 pounds, which is almost exactly the same as the 87·3842 pounds.

Trials of the machinery of the United States steam-launch No. 4, *with screw G, made on the* 17*th of February*, 1870, *with the vessel secured to the wharf at the Mare Island navy-yard, Cal.*

During the experiments with screws A to H, made with the steam-launch No. 4, in the bay in front of Mare Island, two trials of screw G were made with the vessel secured to the wharf of the navy-yard, at right angles to the current, from the effect of which it was also shielded by the projecting wharf, so that the resistance of the screw was no more affected by the current than if the trial had been in still water. The vessel's draught of water was the same as during the experiments in the bay, and the same indicators and dynamometer were employed.

The trials were made on the 17th of February, 1870, and each lasted thirty minutes, during which a continuous dynamometer-diagram and indicator-diagrams were taken from each end of each cylinder as rapidly as possible; all preparations facilitating dispatch having previously been made.

The machinery was operated for an hour before commencing the trials, to bring it into normal working condition; and during the trials, the steam-pressure in the boiler, the height of the barometer, and the temperatures of the external atmosphere in the shade, of the engine-room, and of the water in the bay, were taken at the end of every three minutes. The number of double-strokes made by the engines' pistons was shown by the register.

The objects of the experiments were to ascertain: 1st. How nearly the thrust of the screw followed the proportion of the square of the number of revolutions made by it in equal time, under the extreme conditions of widely varying power and with the screw acting always at the same place, the water flowing to the screw without the screw

advancing through the water. 2d. To what extent the proportion of dynamometer-power varied from the indicated power under these extreme conditions, and with the greatly varying speeds of pistons and pressures upon them. 3d. The pressure upon the pistons required to work the engines, *per se*. To determine the 3d, the engines, after the completion of the trials, were uncoupled from the line-shafting, and worked at various speeds of piston with the feed-pump pumping at its proper rate to supply the boiler, a considerable number of indicator-diagrams being taken at each speed from each end of each cylinder. The results varied but very slightly, and with the addition of a trifle for the friction of the line-shafting, gave two pounds per square inch of pistons for the pressure required at all speeds of piston to work the unloaded engines.

The data and results of these wharf-trials will be found in the following table, No. 8, arranged in two columns, headed respectively "1st trial", and "2d trial." In the "1st, trial" the number of revolutions made by the screw in equal times was $(\frac{99}{35}:\frac{900}{733}=)$2·796 times more than in the "2d trial" a sufficiently great difference to strongly mark the consequences. The squares of the number of revolutions made by the screw in equal time during each trial, compare as 7·8176 and 1·0000 respectively.

The pressure (2 pounds per square inch of pistons) required to work the engines, *per se*, being deducted from the gross effective indicated pressure per square inch of pistons, leaves a quantity called the "net pressure," which, in the two trials, should have the same ratio as the squares of the number of revolutions made by the screw in equal time. The net pressures compare as $(\frac{98}{31}:\frac{0}{7}=)$ 7·1533 to 1·0000. We have seen that the squares of the number of revolutions made by the screw in equal time compared as 7·8176 to 1·0000, which was doubtless caused by the water not flowing in with sufficient rapidity to solidly fill the displacement by the screw as fast as formed. The discrepancy is considerable; the pressure at the high speed of screw being $8\frac{1}{2}$ per centum less than it should have been, had the water on which it acted been as solid as at the low speed. It was observed constantly, during the trials, that there was no surface-current of water flowing from the bow towards the stern to replace the water displaced by the screw. On the contrary, the surface-water was absolutely quiescent; it had no movement in any direction. The water supplying the screw came up from beneath in nearly a vertical column.

The depth of the water at the wharf was very considerable, and it had a free movement between the bottom and the vessel's keel. An unbroken wave or elevation of water covered the screw during its action; the height of this wave varying, of course, with the rapidity of the rotation of the screw.

In the "1st trial," the dynamometrical horse-powers is $\left(\frac{24 \cdot 827}{27 \cdot 916}=\right)$ 0·8894 of the net indicated horse-powers developed by the engines.

In the "2d trial" the dynamometrical horse-powers is $\left(\frac{1 \cdot 255}{1 \cdot 396}=\right)$ 0.8990.

The thrusts of the screw, per dynamometer, in the two trials, compare respectively as $\left(\frac{1093 \cdot 5}{154 \cdot 5}=\right)$ 7·0777 and 1·0000; while the corresponding net pressures on the pistons compare as 7·1533 and 1·0000.

The distribution of the power, calculated as hereinbefore described, will be as follows for the two wharf trials, namely:

Distribution of the power during the 1*st trial at the wharf.*

	Horse-powers.		Per centum.
Gross effective indicated horse-powers developed by the engines,	28·486		
Power required to work the engines and shafting, *per se*,	0·570		
Net power applied to the shaft,	27·916	or	100·00
Power absorbed by the friction of the load,	2·094	or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades,	0·878	or	3·14
Power expended in the displacement of the water by the screw,	24·944	or	89·36
Totals,	27·916	or	100·00

The power expended in the displacement of the water by the screw as directly measured by the dynamometer, was 24·827 horses.

Distribution of power during the 2d trial at the wharf.

	Horse-powers.	Per centum
Gross effective indicated horse-powers developed by the engines, ...	1·600	
Power required to work the engines and shafting *per se*, ...	0·204	
Net power applied to the shaft, . .	1·396 or	100·00
Power absorbed by the friction of the load, .	0·105 or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades, .	0·040 or	2·88
Power expended in the displacement of the water by the screw, ...	1·251 or	89·62
Totals, ...	1·396 or	100·00

The power expended in the displacement of the water by the screw as directly measured by the dynamometer, was 1·255 horses.

During the "1st trial" with the vessel stationary at the wharf, the screw made 99·9 revolutions per minute, with a net pressure of 98 pounds per square inch of pistons; and when steaming freely at full power, with the same immersion of the screw, and a net pressure of 94·4132 pounds per square inch of pistons, (Table No. 5, line 8, column h,) the screw made 151·0832 revolutions per minute. Increasing the latter number in the ratio of the square roots of the net pressures, we have ($\sqrt{94{\cdot}4132} : \sqrt{98{\cdot}} :: 151{\cdot}0832 :$) 153·9236, the number of revolutions that would have been made with the vessel steaming freely, had the net pressure on the piston been 98 pounds per square inch. Hence it follows that, *with equal net pressure upon the pistons the screw will make* $\left(\frac{153{\cdot}9236}{99{\cdot}9}=\right)$ 54·08 *per centum more revolutions in equal time when the vessel is steaming freely than when it is held stationary at the wharf.*

Again, it will be seen by examining lines 5 and 8, column c, Table No. 5, that when the vessel is steaming freely with a net pressure upon the pistons of 39·2660 pounds per square inch, the screw makes 97·9321 revolutions per minute. Increasing this net pressure in the ratio of $97{\cdot}9321^2$ to $99{\cdot}9^2$, we have, for 99·9 revolutions of the screw per minute when the vessel is steaming freely, the net pressure of 40·8602 pounds per square inch. Hence it appears that, revolution for revolution, there was required when the vessel was stationary at

the wharf $\left(\frac{98{\cdot}0000 - 40{\cdot}8602 \times 100}{40{\cdot}8602} = \right)$ 139·84 per centum more pressure to turn the screw then when the vessel was freely under way.

Of course the above two determinations only apply rigorously for the speeds of vessel at which they are made. The results show an enormously greater proportional resistance of the screw when the vessel is stationary at the wharf than when steaming freely under way than is found in the case of large screw-steamers having considerable *length*, and doubtless arises from the fact that when the launch—a small and very *short* vessel—was steaming freely under way, the water did not reach the screw as solidly as it does in the case of long screw-steamers, while, when steaming at the wharf, the difference in this particular was very greatly less.

Table No. 8, *containing the data and results of the trials on the* 17*th of February*, 1870, *of the machinery of steam-launch No.* 4, *with screw G, the vessel being secured to the wharf of the Mare Island navy-yard, California.*

	1st. trial.	2d. trial.
TOTALS.		
Duration of the trial in minutes	30·	30·
Number of double strokes of engines' pistons and of revolutions of the screw	2,997·	1,072·
TEMPERATURES.		
Temperature, in degrees Fahrenheit, of the external atmosphere	54·	59·
Temperature, in degrees Fahrenheit, of the water in the bay	52·	53·
Temperature, in degrees Fahrenheit, of the engine room	80·	83·
ENGINES.		
Number of double strokes made per minute by the engines' pistons	99·900	35·733
Steam pressure in the boiler, in pounds per square inch above the atmosphere	107·	19·
Position of the throttle-valve	Wide open.	Wide open.
Fraction of the stroke of the pistons completed when the steam was cut off	0·858	0·858
Thrust of the screw, in pounds, per dynamometer	1.093·5	154·5
Height of the barometer, in inches of mercury	29·85	29·84
STEAM-PRESSURES IN CYLINDERS PER INDICATOR.		
In pounds per square inch above zero at commencement of stroke of pistons	119·0	32·1
In pounds per square inch above zero at point of cutting off the steam	112·3	30·1
In pounds per square inch above zero at end of stroke of pistons	93·7	26·5
In pounds per square inch above zero against the pistons during their stroke	18·4	16·1
Mean gross effective pressure on pistons, in pounds per square inch.	100·0	15·7
Mean total pressure on pistons, in pounds per square inch	118·4	31·8
Mean net pressure on pistons, in pounds per square inch	98·0	13·7
POWER.		
Gross effective indicated horse-powers developed by the engines	28·486	1·600
Total horse-powers developed by the engines	33·728	3·240
Net horse-powers developed by the engines	27·916	1·396
Dynamometrical horse-powers developed by the engines	24·827	1·255

Trial of the machinery of the United States steam-launch No. 4, *made on the* 30*th of March*, 1870, *with screw G*, *the vessel being secured to the wharf of the Mare Island navy-yard*, *California*, *and having its steam raised six inches and held suspended by a floating crane.*

This experiment, the data and results of which will be found in the following table, No. 9, was made with the vessel secured to the wharf of the Mare Island navy-yard in such a way that the keel was at right angles to the current. The stern of the vessel was raised six inches and held suspended by a floating crane, which, in common with the vessel, rose and fell with the tide. The object of thus suspending the stern of the vessel above the level at which it floated when resting in the water with its screw not in action, was to enable the engines to make a greater number of double strokes of pistons with the same piston-pressure, in a given time, than they would have done without such suspension; in fact, to make nearly the same number per minute they would have done with the vessel in free motion and the same piston-pressure.

The principal objects of the experiments were:

1. To ascertain the rate of combustion of anthracite in the furnace under the experimental conditions.

2. To ascertain the economic vaporization by the boiler with anthracite at this rate of combustion.

3. To ascertain the indicated and dynamometrical horse-powers developed by the engines.

4. To ascertain the cost of the indicated and of the dynamometrical horse-powers, in pounds of anthracite, in pounds of the combustible portion of the anthracite—that is, of the portion which remains after deducting the refuse in ash, clinker, etc.—and in pounds of feed-water consumed per hour.

5. To ascertain the condensation of steam in the cylinders.

In making the experiment, the same indicators and dynamometer were used as were employed throughout all these experiments. The anthracite was carefully weighed on the wharf and delivered into the fire-room as fast as consumed. The refuse from it in ash, clinker, etc., was collected and weighed in the dry state at the end of the trial, and on the same scales as the anthracite. The feed-water was accurately measured in an iron tank placed on the wharf. From this tank the water was delivered through a hose into a smaller tank on

board the vessel, from which it was pumped in to the boiler by the feed-pump of the engines. In passing from the last tank to the boiler the feed-water traversed the "heater" and had its temperature raised by the exhaust steam of the engines. The feed-water was rain-water.

The temperatures of the external atmosphere, of the engine and boiler room, of the water in the bay, of the feed-water in the tank and when it entered the boiler, were taken every fifteen minutes, by the usual mercurial thermometers. At the same intervals there were noted the steam-pressure in the boiler and the height of the barometer. The throttle-valve was kept wide open, and the point of cutting off the steam remained constant during the trial. The number of double strokes made by the engines' pistons was taken by a counter.

An indicator-diagram was taken every fifteen minutes from each end of each cylinder. The diagrams from the dynamometer were practically continuous.

All the observations were recorded, at fifteen minutes' intervals, in a tabular record.

In commencing the experiment, the engines were operated several hours to bring them into proper adjustment, and the fires to steady action. The latter were then thoroughly cleaned and made about six inches thick, the height of the water in the boiler glass guage marked, the steam pressure in the boiler, and the time noted, and the experiment held to commence. At its end, the fires were again thoroughly cleaned, and left of the same thickness as at the commencement, with the water at the same level in the boiler, and having the same steam-pressure upon it.

RESULTS.

The maximum rate of combustion that could be sustained was 24·655 pounds of anthracite per hour per square foot of grate-surface with a blast up the chimney given up the exhaust of the two cylinders working at right angles to each other, and having a steam-pressure at the end of the stroke of the pistons of 66·8 pounds per square inch above the atmosphere. The number of exhaustions made per minute was 472. The per centum of this anthracite in refuse being 16·23, there were consumed of its remaining or combustible portion, 20·653 pounds per hour per square foot of grate-surface. To have sustained this rate of combustion with natural draught would have required a chimney 60 feet high above the level of the grate.

The economic vaporization for this fuel and rate of combustion, and for the type and proportion of boiler, was very high, being 9·687 pounds of water vaporized by one pound of the combustible portion of the anthracite from the temperature of 212 degrees Fahrenheit, and under the standard atmospheric pressure of 29·92 inches of mercury.

The condensation of steam in the cylinders, other than that due to the development of the power, was 31·76 per centum of the weight of steam generated in the boiler. This large per centum is due to the small size of the cylinders. With large cylinders, working without a condenser, and with the same low measure of expansion—the steam not being cut off until 0·858 of the stroke of the pistons was completed—the condensation, other than that due to the development of the power, would not have exceeded one-tenth what it proved to be with these small cylinders. Nothing could more strikingly show the necessity for using highly superheated steam with small cylinders. The pistons and valves of these were perfectly tight, and the cylinders and steam-pipes were well protected from radiation.

The distribution of the gross effective indicated power developed by the engines, calculated in the manner hereinbefore explained, is as follows, namely:

	Horse-powers.		Horse-powers.
Gross effective indicated horse-powers developed by the engine, ...	27·221		
Power required to work the engines and shafting, *per se*, ...	0·673		
Net power applied to the shaft, . .	26·548	or	100·00
Power absorbed by the friction of the load, .	1·991	or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades, . .	1·455	or	5·48
Power expended in the displacement of the water by the screw, ...	23·102	or	87·02
Totals, ...	26·548	or	100·00

From the above calculation, it appears that the power expended in the displacement of the water by the screw working with the vessel secured to the wharf, or, what is the same thing, the dynamometrical power by calculation, was 23·102 horses. This power, as directly measured by the dynamometer, was 23·025 horses, or sensibly the same.

During the trial, the force of the blast in the chimney was ascertained by direct measurement. An iron pipe of small diameter was placed immediately over the blast-nozzle, and half an inch above it. This pipe extended vertically to the top of the chimney, over the edge of which it was bent and brought down to a convenient distance, where it was joined to an inverted glass siphon containing mercury. The pressure of the blast in one leg of the siphon forced the mercury up the other leg, and the height of the mercurial column from the mercury-level in one leg to that in the other leg measured it. The mean of a great many observations showed that when the steam pressure in the boiler was 102 pounds per square inch above the atmosphere, the height of the column was 6·6 inches, equivalent to a pressure of 3·24 pounds per square inch.

(To be continued.)

BRIDGE SPECIFICATIONS.

By Joseph M. Wilson, C.E.

Engineer of Bridges and Buildings, Pennsylvania Railroad.

The following specifications of bridges now actually under erection may be of interest to those who have charge of such work, and are here offered with that intention.

SPECIFICATIONS

For masonry of street bridge to be erected over the Pennsylvania Railroad, at Penn avenue, in the City of Pittsburgh, Pennsylvania.

The foundations to be dug out to a depth of six (6) feet below the natural surface of the ground, or to such greater depth, if found necessary, as the Engineer may decide, and to be filled in for the depth of three (3) feet with concrete.

The concrete is to be formed of a hard durable stone, to be approved of by the Engineer, broken into angular fragments of a size to pass through a two-and-a-half (2½) inch ring, and to be screened.

This stone to be mixed with clear, sharp, river sand, and hydraulic cement, in the proportion of one (1) part cement, one (1) part sand, and four (4) parts broken stone. This must not be mixed in a larger amount than requires one (1) barrel of cement at a time, and must be used as mixed, not being allowed to lay, and then remixed with water and used.

The concrete must be prepared by first spreading out the cement and sand in the proper proportions on a platform of rough boards, and thoroughly mixing then in a dry state. The proper quantity of stone is then to be added, and after again thoroughly mixing the whole, water is to be added as much as necessary to bring the mass to the proper consistency; the materials being mixed as the water is added, until all the materials are thoroughly incorporated, and the surface of each stone is well coated with mortar. This concrete must be placed in the foundations in layers not over a foot thick, and must be either thrown from a height of not less than ten (10) feet, or else each layer must be well rammed until a film of water appears upon the surface, but not enough to make it quake.

Time must be given for the concrete to become firm before masonry foundation is commenced upon it, as heavy pressure tends to retard the setting.

The masonry will be rock range pitch face; the stone to be accurately squared, jointed and bedded, and laid in courses not less than twelve (12) inches thick, nor exceeding twenty-four (24) inches in thickness: decreasing from bottom to top of pier or abutment. The stretchers shall in no case have less than sixteen (16) inches bed; and for all courses above sixteen (16) inches, at least as much bed as face. They generally shall be at least four (4) feet in length. The headers shall be of similar size with the stretchers, and shall hold the size in the heart of the wall that they show on the face, and be so arranged as to occupy one-fifth ($\frac{1}{5}$) of the face of the wall, and when the thickness of the wall will admit of their interlocking, they will be disposed in that manner. When the wall is too thick to admit of that arrangement, stones not less than four (4) feet in length will be placed transversely in the heart of the wall to connect the two opposite sides of it. The stones for the heart of the wall will be of the same thickness as those in the face and back; bedded the same as the face stone but not jointed, and must be well fitted to their places, any remaining interstices to be filled with small sound stones or chips. The face stones

to be set in cement mortar; the interior stones to be laid dry, and every course to be thoroughly grouted. The proportion of sand, cement, and lime in the mortar and grout, to be as directed by the Engineer.

The stones forming the masonry will be generally left with their faces as they come frome the quarry, unless the projection above the neat line should exceed two (2) inches, in which case they shall be roughly scabbled down to that point.

Such coping and such posts for railing as shall be indicated on the drawings, or shall be directed by the Engineer, shall be hammer dressed to the required sizes, and placed as shown.

In all masonry the stone must be of a hard and durable quality, either Derry, Massillon, or Freeport, of good size and shape, to be approved of by the Engineer.

The coping, bridge seats, and posts being the hammer dressed work, are to be of Massillon stone.

Such portions of the masonry as the Engineer may require to be laid in lime or hydraulic cement, to be so laid; the Pennsylvania Railroad Company furnishing, or paying for the lime or cement used, and the contractor furnishing a suitable protection for the cement from the weather.

If, in the progress of the masonry, an increase in the number of headers specified should be required by the Engineer, such additional number shall be laid in the work as he shall designate.

The whole of the construction to be in strict accordance with the drawings furnished by the Engineer of Bridges and Buildings of the Pennsylvania Railroad Company, and under the direction of the Engineer in charge of the work.

SPECIFICATIONS

For superstructure of railroad bridge to be erected near Morrisville Station, on the New York Division of the Pennsylvania Railroad.

General Description.—The superstructure is to be constructed on the triangular girder system, and to consist of four spans, square to the line of the railroad, three of them deck bridges of three trusses, and one a half-through bridge of two trusses, numbering from the west end, the railroad tract having a curvature of five and a half degrees.

The trusses throughout are to be composed entirely of wrought iron, except rollers and bolster blocks on the piers and abutments, having

wrought upper chords of channels and plates, wrought iron upset weldless link lower chord, and wrought iron braces, all with link ends, to be upset without weld. All joints are to be made with pin connections, and sleeve nuts are to be introduced in the laterals and diagonals for adjustment.

The deck spans are to have timber floorbeams, and the half-through span wrought iron built cross girders; white oak track stringers are to be used throughout. The bolsters and abutment plates are to be of wrought iron.

The general dimensions are as follows:

Span No. 1.

Distance, centre to centre of end pins, ...	73 ft. 6 in.
Number of panels, ...	4
Number of sub-panels, ...	8
Length of each panel, ...	18 ft. $4\frac{1}{2}$ in.
Length of each sub-panel, ...	9 ft. $2\frac{1}{4}$ in.
Height of truss, centre to centre of chords, . .	7 ft. 3 in.
Distance, centre to centre of trusses, . . .	9 ft. 9 in.

Spans Nos. 2 *and* 3.

Distance, centre to centre of end pins, . . .	53 ft. 6 in.
Number of panels, ...	4
Number of sub-panels, ...	8
Length of each panel, ...	13 ft. $4\frac{1}{2}$ in.
Length of each sub-panel, ...	6 ft. $8\frac{1}{4}$ in.
Height of truss, centre to centre of chords, . .	5 ft. 6 in.
Distance, centre to centre of trusses, . . .	9 ft. 6 in.

Span No. 4.

Distance, centre to centre of end pins, . . .	57 ft. 6 in.
Number of panels, ...	6
Number of sub-panels, ...	12
Length of each panel, ...	9 ft. 7 in.
Length of each sub-panel, ...	4 ft. $9\frac{1}{2}$ in.
Height of truss, centre to centre of chords, . .	5 ft. 9 in.
Distance, centre to centre of trusses, . . .	26 ft. 6 in.

In the fourth span, the cross girders occur at every sub-panel.

Wrought Iron.—All the wrought iron must be of the best quality, tough and fibrous, free from flaws and cracks along the edges. All the iron in the tensile members, lower chords, tension laterals, diagonals, bolts, etc., etc., must be doubled rolled from the muck bar direct, no scrap will be allowed, and must be capable of sustaining an ultimate stress of sixty thousand (60,000) pounds per square inch, on a turned-down or grooved section, with no permanent set under twenty-five thousand (25,000) pounds per square inch. When tested to breaking, if so required by the Engineer, the links and rods must part through the body, and not at the pin hole in the head.

All workmanship must be first-class. All abutting surfaces must be planed or turned, so as to insure even bearings, and protected by white lead and tallow before shipment. No error of over one sixty-fourth ($\frac{1}{64}$) of an inch will be allowed in the lengths of bars between centres of pin holes, nor shall there be any variation in pins or pin holes of over one hundredth ($\frac{1}{100}$) the diameter of the pin; said holes to be accurately drilled. All riveted plates must come in close contact where abutting, and the rivet holes must be spaced accurately and truly opposite. Rivets must completely fill the holes and have full heads, and when necessary, they must be countersunk. Thickening washers are to be used whenever required to make the joints perfectly snug and tight.

Castings.—The cast iron work is to be true and sound, free from flaws and defects of any kind, and may be green sand castings, but should be of good tough iron, the lines sharp and clear and according to the drawings.

No rough or crooked castings will be accepted. All bolt and pin holes must be accurately drilled; all abutting surfaces must be planed, if necessary to insure even bearings and neat close fittings, and the castings are to be perfectly dressed and fitted up to make a good job generally, when put in the bridge.

General Conditions.—The whole of the construction to be in strict accordance with the drawings furnished by the Engineer of Bridges and Buildings of the Pennsylvania Railroad Company. In all cases figures are to be taken in preference to any measurement by scale. No alteration to be made unless authorized by the Engineer. All work to receive one coat of red lead in oil before being sent to the site.

Chemistry, Physics, Technology, etc.

ON THE LAWS OF ADHESION.

From Der Naturforscher, vol. viii, page 60. *Translated by Cleveland Abbe.*

Stefan has communicated to the Vienna Academy of Sciences a memoir on the nature and laws of adhesion, which is the result of elaborate investigations, and must be considered as of high value in this department of physical research. In giving a general account of his results, he says: "By apparent adhesion I intend to designate the phenomena that are shown when two plane surfaces, after being brought into contact, are separated from each other again by the direct application of force. This phenomenon has, thus far, been generally considered as the result of adhesion, that is to say, a result of the attraction of molecular forces between the neighboring portions of the two plates; and there have already been measurements made by others of these adhesive forces. In these cases there occurs no immediate contact of the two plates, but there lies between them a stratum of air of comparatively slight thickness. If, for instance, we choose for the experiment two glass plates, they will generally be found not to show the Newtonian color rings. These latter can, in fact, only be made to appear when we apply a very considerable pressure to the perfectly plane plates. If, therefore, in such a case, molecular forces are called into play between the two plates, it would follow that the so-called radius of molecular activity would have a magnitude far greater than is indicated by other classes of experiments. Still more remarkable will the phenomenon appear if we dip the two plates under water. We can, in this case, detect an apparent attraction between the plates when their distance is as great as one millimeter.

In order to obtain definite data, one of these plates was hung upon a balance, so that its lower surface was horizontal and in equilibrium. The second plate was under the first, and also horizontal; on it three pieces of wire were laid, and then the upper plate allowed to descend

until it rested upon these. The diameter of the wires determined the initial distance of the two plates. In order to separate the upper plate from the under, it was necessary to place a slight counterpoise in the opposite pan of the balance. From experiments of this kind it was found that this weight must be greater, the finer the wires that lie between the plates, and the larger the plates themselves. The weight of this counterpoise depended also upon the nature of the fluid in which the plates were dipped.

But the exact measurement of the weights necessary to raise the upper plate, leads, in repeated experiments under similar conditions, to many contradictory results; so that it seemed that the determination of the force necessary to separate the plates, had no physical meaning; that in fact in these phenomena we have to do not with a statical but with a dynamical problem. Almost any weight was found to be sufficient to raise the upper plate from the lower one, only the time in which this was accomplished was greater in proportion as the weight was less. That which it is important to measure, in this connection, is the continuous movement in which the upper plate is set, by the adding of a small counterpoise, and in consequence of which it immediately slowly separated itself from the lower plate.

This movement, at first, is an extremely slow one, the position of the index of the scale beam for a long time being apparently fixed, especially when the wires laying between the plates are fine, and the weight itself is small, but we can assure ourselves that the movement begins immediately that the weight is laid in the scale, by using appropriate optical aids. If, for example, we bring the plates so near to each other that by using mono-chromatic light we can observe the interference of the rays of light that pass between the plates, then immediately after laying a small weight in the scale beam, the interference bands slowly draw together, and soon become so fine as to be invisible; although one cannot notice the least movement of the index of the balance. Thus we understand how it happens that by confining our observations to a short interval of time, we have hitherto made the mistake of assuming that there existed for a moment a statical equilibrium. Now, however, that the dynamic character of the phenomenon is understood, it is no longer difficult, at least in general terms, to understand the various steps of the process, which are very nearly as follows:

Assuming the two plates to be, at first, at a given distance from each other, at rest, and the upper plate counter-balanced by a proper

weight. If we add then a small additional weight to the scale beam, at once the upper plate thereby receives an exceedingly small upward impulse, and the space between the two plates is increased. The fluid that is found within this space experiences a dilatation, and in consequence of this, there is a diminution of the hydrostatic pressure between the plates. If, however, the upper plate is pressed upward by the fluid underneath it, slightly less than before, still the pressure of the fluid above this plate remains the same, and a portion thereof remains uncompensated, which portion will therefore resist the upper movement due to the weight in the pan of the balance. Between these two forces, no equilibrium can be established, since the diminution of the hydrostatic pressure between the plates induces as a consequence, an inflow between the plates from the outer fluid under a permanently higher pressure; thereby the difference of pressure on the upper and lower sides of the upper plate is again diminished; the counterpoise again acts to elevate the upper plate, and the same operations are repeated over and over.

The force arising from the dilation of a fluid, and opposed to the draught of the counterpoise, has a greater effect, the more slowly the fluid flows from without into the space between the plates. The velocity of this flow is, for the same difference of pressure, smaller in proportion to the section of the current and the length of its path. Therefore, the velocity with which the plates separate from each other, will, under otherwise similar circumstances, be smaller in proportion as the two plates are nearer together, and of larger size. Furthermore, with the same difference of hydrostatic pressure, the velocity of the current will be smaller, the greater the viscosity or the interior friction of the fluid. Therefore, the velocity with which the plates separate from each other under otherwise similar circumstances is dependent upon the nature of the fluid in which the plates are immersed, and such a manner that the velocity is smaller the more viscous the fluid is.

For the exact determination of these relations, I have made a number of experiments in which I have confined myself to the observation of the time which the upper plate occupies in moving to a given distance from its initial distance from the under plate. The initial distance of the plates is given by the diameter of the three pieces of wire laid between them; the final distance is determined by means of a mark on the auxilliary arc of the balance, by means of

which the movement of the index is observed. The distance between these two positions was in all of my observations 0·26 of a centimeter. Some very simple relations between the data employed have been deduced from these observations. First, it resulted very plainly, both for the movement of the plates in liquids, and also in the air, that the time required to separate the two plates from the initial to the final distance, is inversely proportional to the weight of the counterpoise. Second, this time is for the same counterpoise greater, according as the original distance of the plates is smaller; it increases, *i. e.*, in a quadratic proportion, when the distance of the plates diminishes in simple proportion. Third, the time is furthermore greater, the larger the plates are that are used in the experiment, for pairs of plates, similar in all other respects, the times vary, as the fourth powers of the radii of the plates. Finally, as regards the influence and nature of the fluids; the experiments with water, solutions of salt, and with alcohol, and air, give coincident results, viz.: that the time in question is proportional to that occupied by equal volumes of these fluids flowing under the same pressure through a capillary tube. It is thus rendered evident that the phenomena in question, are problems in hydrodynamics, and the conclusion of Stefan's memoir, is an endeavor to devise a theoretical solution of these problems. These solutions are based upon the following considerations:

If a weight is laid in the pan of a balance which is otherwise in equilibrium, the force of gravity, during the sinking of the weight performs a work whose equivalent is found partly in the living force of the weight, but principally in that of the moving portions of the balance. In the present experiments, however, the movement of the balance is so exceedingly slow that its living force is very small in comparison with the work of gravity. The latter, therefore, must have its equivalent in some other work, and this is found in that work which is necessary in order to maintain the current of fluid flowing from without into the space inclosed between the plates. We have, then, to find an expression for this work, in order, by equating this with the work of gravity to be able to determine the motion of the plates. From the various conditions which the current must fulfill, it is possible to devise a formula for the velocity of the fluid at every point between the plates, which formula, if not perfectly accurate, still, must represent with great approximation the actual conditions. Based upon this formula, we can now calculate the work necessary to

be done, in order to maintain the current, and by equating this work with that of the sinking counterpoise, we obtain an equation from which we may determine the time occupied by the upper plate in order to move from one position to another, with respect to the lower plate. The actual formula found by Stefan, corresponds to all the various relations to which the experiments have led. This formula enables us, also, to compute from the experiments the coefficients of internal friction; and there results the coefficient 0·0108, as the coefficient for water at a temperature of 19°. For air, at the same temperature, we have 0·00183, which two numbers agree exactly with those that can be deduced from the experiments of Poisenille, and with those that have already been determined by Maxwell and O. E. Meyer. This agreement between the results of the experiments and the theoretical development, could, however, only be arrived at under the assumption that the fluid is not perfectly quiet at the surfaces of the plates, but slides along these surfaces, while on the other hand, the experiments on the currents of fluids through capillary glass tubes lead to the presumption that the fluid immediately in contact with the sides of capillary tube has no movement. For the complete explanation of this difference between the results of different observations, there is still necessary a further series of experiments. The experiments in this present essay, resolve merely the particular question, viz.: as to the nature of the *apparent* adhesion, and thus enable us to give this phenomenon its right place in molecular physics.

Dangerous Explosive Mixture.—The Irish Court of Queen's Bench recently granted a motion to draw out of court a sum of £1500 tendered by the Governor and Directors of the Apothecaries Hall of Ireland, as compensation for the consequences of their mistake in selling a packet of sulphide of antimony for oxide of manganese.

A man named Marsden, intending to make oxygen, mixed chlorate of potash with the sulphide of antimony, instead of black oxide of manganese, and from the explosion which followed, he was killed, and his wife severely injured.

Chlorate of potash detonates with great violence when heated with sulphur or carbon, or with compounds containing these elements. Too much care cannot be exercised in making oxygen to be assured that the oxide of manganese used is free from contamination.

REPORT ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.†

(Continued from Vol. lxx, page 52.)

The air is driven by means of a blast, at a pressure of 3 to 4 c. m. of mercury through a sheet iron box filled with caustic lime, and then conducted into the retort from above. The temperature of the latter can be judged by means of an aperture, which can be closed with an iron stopper. The air gives off only about the half of its oxygen, so that, for 1 volume of oxygen, 10 volumes of air must be passed through, the residue escaping into the atmosphere.‡ In about five minutes the revivification of the reduced mass is completed, when the stream of air is cut off by means of a cock with a triple perforation, and a current of superheated steam is passed through for five minutes, whilst immediately afterwards the gas which issues below the grate is conducted into condensers. Here a fine descending rain of cold water frees the oxygen from steam, and it enters the gasometer under the pressure of a column of water of from 8 to 10 c. m. in height. In this manner, reduction and oxidation alternate at intervals of five minutes. Not until six hours have elapsed does it become necessary for a more complete revivification of the mass to pass atmospheric air over it for an hour, for in five to six hours the yield of oxygen sinks from its original quantity down to the half, or even the third. The cocks are set at Vienna by a self-acting movement. The longer watery vapor is introduced, and the retorts thus freed from atmospheric air before opening the communication with the gasometer, the purer is the oxygen. Half a minute suffices to bring down the nitrogen to 15 per cent., if the useless space in the retorts is kept as small as possible. If, as is easily practicable, the nitrogen is brought down

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† From the *Chemical News*.

‡ Latterly, Tessié du Motay has attempted to convert the escaping nitrogen industrially, first into nitride of titanium, and then into ammonia.

to 4 per cent., there is a greater waste of oxygen. To be certain that the amount of nitrogen remains within the limits of from 10 to 15 per cent., samples are taken from the gasometer in graduated tubes, and the oxygen is absorbed by means of known quantities of potash and pyrogallic acid, a reaction which, even in inexperienced hands, gives quick and accurate results.

As any cooling of the retorts below a dark red heat diminishes the yield, care is taken to heat both the air and steam to about 300° C. At Pantin, where there are several groups of 10 retorts each, two of them are filled with pumice-stone, and serve for heating the air and the steam. The composition of the mass is 2 molecules of $NaOH$, 1 molecule of MnO_2, and the fifth of a molecule of oxide of copper, which merely serves to separate the other ingredients and render them more accessible to the influence of steam and air. At Comines, the black oxide of manganese is regenerated in the ordinary manner from chlorine residues, and is almost pure; its price is 2 francs per kilo. The great cost of this fundamental article is not of importance, since it can be used the longer, the more carefully the air is freed from carbonic acid. If, in consequence of some inevitable interruption of the process, the mass absorbs atmospheric carbonic acid, it is simply requisite to heat to redness, and to pass a current of steam over it till the escaping vapors cease to render lime water turbid. The temperature is then raised and air passed over the mass, when it regains its original efficacy. The average duration of a retort is one year.

Tessié du Motay's process yields oxygen at 90 per cent., at the cost of 15 to 30 centimes per cubic meter,* or, according to the experiments of Kuppelwieser, in Vienna,† 3 florins per 1000 cubic feet, a price which agrees with the former, and which scarcely exceeds that of coal-gas. We may regard this process as the final and successful solution of the problem as to the economical and rational production of oxygen.

We have still to review a group of projects, which, without any chemical agents, aim at extracting oxygen from the atmosphere by a purely mechanical procedure. They are based upon two physical principles, diffusion or absorption.

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* Phillips, "Der Sauerstoff," 18.

† Kuppelwieser, *Berg. und Hütten Ztg.*, 1873, 354.

Th. Graham, who, in his classical researches, investigated the laws of the escape of gases through narrow apertures, made known in 1866* that air which is drawn through a fine chink in a plate of caoutchouc, passes in the constant proportion of 41·6 per cent. of oxygen, to 58·4 per cent. of nitrogen, the half of the atmospheric nitrogen being held back. This mixture causes glowing chips of wood to burst into flame. Deville† tested the industrial value of this process, and found that the time required was too long.

Absorption has been utilized in two distinct forms. Montmagnon and De Laire in 1868 took out a French patent,‡ based upon the observation of Angus Smith,|| that charcoal absorbs from the air more oxygen than nitrogen. According to them, 100 liters of wood-charcoal absorb 925 liters of oxygen, and only 750 liters of nitrogen. If moistened with water, they give off 350 liters of oxygen and 650 liters of nitrogen, so that 575 liters of oxygen and 55 (100 ?) liters of nitrogen remain and can be extracted with the air pump. By repeating this process with the same gaseous mixture, they succeeded in bringing the oxygen almost in a state of purity. Whether this process has ever been carried out on the large scale is not known. An attempt has, however, been made with Mallet's method.§ based on the property of water to absorb oxygen rather than nitrogen.

The coefficients of absorption of the two gases are 0·025 for N, and 0·046 for O. If multiplied by the proportion of their bulk in the atmosphere, 0·79 for N, and 0·21 for O, these numbers give the volume proportion of both gases in water = 0·0197 N and 0·0097 O; or, the air absorbed in water contains, in one volume, 0·67 N and 0·33 O. If the unabsorbed nitrogen is allowed to escape, and the absorbed gaseous mixture, richer in oxygen, is withdrawn from the water and again absorbed, it follows, from the multiplication of the two coefficients of absorption with the volume proportions of 0·67 N and 0·33 O, that the gaseous mixture now taken up has the composition 0·525 N : 0·475 O; a third absorption raises the result to 0·375 N : 0·625 O; a fourth to 0·25 N : 0·75 O; and a fifth to 0·15 N : 0·85 O, the proportion in

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* Graham, *Comptes Rendus*, lxiii, 471.

† Deville, Wagner, *Jahresberichte*, 1867, 216.

‡ *Bull. de la Soc. Chim.* [2], xi, 261.

|| Angus Smith, *Proc. Roy. Soc.*, xii, 424.

§ Mallet, *Dingler's Polyt. Journ.*, cic, 112.

which the two gases occur in Tessié du Motay's oxygenous mixture. After the eighth absorption, the gas is almost pure oxygen (0·973 O and 0·027 N).

Mallet's apparatus consisted of a larger or smaller number of strong iron water holders, connected with each other by means of suction and forcing pumps. Into the first air is driven through fine apertures at a pressure of about five atmospheres. The unabsorbed nitrogen escapes by a valve. The absorbed gas is now extracted by the second pump from the first receiver, and forced into the second. With a series of four receivers the operation lasts five minutes. If the receivers serially decrease in size, the first holding 10 cubic meters, and the last 5, the result of a continuous working of the process is 7760 liters per hour of a gaseous mixture containing 75 per cent. of oxygen, or 168 cubic meters in twenty-four hours. The cost of working, wear and tear, and supervision, are said to be insignificant. Where motive power is cheap, *i. e.*, water-power or the waste heat of metallurgical processes, this method may consequently be applicable, especially for use in such metallurgical operations where a mixture comparatively poor in oxygen is serviceable.

If we sum up the results of our survey of the methods for the industrial prepartion of oxygen, we must place Tessié du Motay's process in the first line, as well tried and proved, and in the second, Mallet's mechanical process as just described.

Finally, we pass to the question: To what applications has oxygen hitherto been put? As the supporter of combustion, we owe to it heat and light; and, as the medium of respiration, it is the condition of life.

If we consider oxygen from these three points of view, its metallurgical applications first draw our attention. What it has already done for the platinum manufacture has been explained above. For the autogenous soldering of lead it has been dispensed with, since hydrogen or coal-gas burnt in atmospheric air gives out a sufficient heat; but the example of this art encourages us in connecting great hopes with the extended applications of oxygen. Says an esteemed practical metallurgist, Clemens Winkler:*—

"As gold, when used for soldering platinum vessels, impairs the

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* Clemens Winkler, *Deutsche Industrie Blatter*, p. 182. *Zeitschrift d. Vereins Deutsch. Ingen.*, xvi, 714.

appearance, since the soldered places appear yellow, in the same manner the whiteness of soft solder is an eyesore when it is applied to colored metals. This evil induced the Prussian Association for the Promotion of Manufacturing Industry to offer a reward for the discovery of a yellow solder—a problem not easy to solve without the prior discovery of a new easily fusible metal of a red or yellow color.* It would be more useful to turn our attention to the autogenous soldering of metals with the aid of the oxy-hydrogen flame, a principle which has achieved such signal triumphs in the treatment of two essentially different metals. Should it not be possible, by the same means, to solder every metal and every alloy with itself, as tin with tin, copper with copper, brass with brass, silver with silver, gold with gold, and even iron with iron, just as we already solder lead with lead and platinum with platinum? The probability is present, and the advantages of such a procedure are manifest. Let us try to conceive the neatness of a workshop in which soldering is performed, not as heretofore, with the soldering-iron or at the forge, but with a light, elegant gas-burner. Imagine the artisan no longer annoyed by radiant heat and by the fumes of charcoal, and able to produce in a moment any temperature required, even the very highest, and again to put an end to it by simply turning a cock. Conceive the solidity of the soldering which no longer depends on cementing two pieces of metal with a foreign matter, but on an actual interfusion of two portions of one and the same metal, and which involves the utmost economy of materials and dispenses with all subsequent work, such as trimming the soldered place with a file. Such evident advantages must overcome every prejudice, and prompt us most urgently to commence a thorough experimental investigation of the question."

But also in the most extensive fields of metallurgy, the preparation of iron and steel, technologists of merit have pointed out the advantages to be derived from cheap oxygen.

Cameron† recommends the use of oxygen, or of air rich in oxygen, as obtained from Mallet's absorption cylinders, instead of ordinary air in blast-furnaces; and we may here remark that the absorption of oxygen in water has been already unintentionally used for this pur-

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* The offer has, therefore, been subsequently withdrawn.

† Cameron, *Berg. u. Hüttenm. Zeitung,* 1871, 132.

pose, although in a form capable of improvement. Br. Kerl* has called attention to the fact that the air from the water-blast is richer in oxygen than common air.

It has also been observed that old charcoal burns more energetically than recent, because the former has absorbed oxygen from the air, a circumstance which has been practically utilized with advantage in refining crude iron.†

Kuppelwieser recommends air rich in oxygen for treating white crude by the Bessemer process, and he is of opinion that the cost of Tessié du Motay's process would not require to be far reduced to render oxygen available for this purpose.‡ A great future appears open here for the utilization of oxygen. Nevertheless, Le Blanc's objection cannot be overlooked, that more infusible crucibles, furnaces, etc., would be required, the cost of which would render the advantage of the process doubtful.

Turning from metallurgy to the production of light, we must admit that, since 1826, when Drummond|| invented his oxy-hydrogen light, and applied it for land-measuring and for lighthouses, no one can have questioned the value of oxygen for this purpose. As the price of the gas was reduced, its application was extended, an example being especially set in America. H. Vogel,§ in the year 1870, found oxygen in successful use at New York, not merely for lighthouses, signals, and the building of houses, but also for aquatic structures and for several applications of the magic lantern. The aquatic operation in connection with the great Brooklyn Bridge over the East river, then in course of erection, was lit up with twelve oxy-hydrogen lamps, which consumed daily 2000 cubic feet of oxygen.** Instead of lime points, the more permanent zircon cones were used, with great advantage. In Paris, also, the Théâtre de la Gaité and the Alcazar were illuminated with a fairy splendor.

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* Br. Kerl, *Grundriss der Hüttenkunde*, i, 217.

† *Journ. Prakt. Chemie*, ci, 397. *Bergwerksfreund*, iii, 513.

‡ Kuppelwieser, *Berg. u. Hüttenm. Zeitung*, 1873, 354.

|| Drummond, "On the Means of Facilitating the Observation of Distant Stations in Geodetical Operations."—*Phil. Trans.*, 1826.

§ Vogel, *Ber. Chem. Gesell.*, iii, 901.

** Vogel says, by mistake, cubic meters.

At the Opera House at New York,* a diagram of about 10 square meters upon a screen of damp muslin was lit up by the aid of a system of powerful lenses, whilst the lamp stood at the back-ground of the stage at the distance of 25 meters, and gave a striking effect. In conjunction with this light, the magic lantern was adopted in America to exhibit apparatus, photographs on glass, and other drawings in large lecture halls, especially since Outerbridge discovered the way of using thin plates of gelatine for the production of lithographs or pen-drawings. The effect is easily conceived if we remember that the oxy-hydrogen flame is 16½ times more brilliant than that of an ordinary burner fed with the same amount of gas.

The daily production of the New York Oxygen Company amounted in 1870 to 30,000 cubic feet, or 850 cubic meters. The gas is delivered in iron cylinders (Robert Grant's patent, New York), 9 inches in diameter and 30 inches long, which are filled with oxygen under a pressure of 20 to 30 atmospheres. The cylinder is sold at 1 dollar per cubic foot, including the oxygen contained in it at ordinary atmospheric pressure. The oxygen, on refilling, is supplied at five cents per cubic foot under the pressure of 1 atmosphere,† an exceedingly high price, more than twenty-two times as great as Kuppelwieser's calculation, as quoted above, although Tessié du Motay's method is in use in New York.

Since 1867, Tessié du Motay has attempted to apply the oxygen light to streets and squares. The places before the Tuileries and before the Hotel de Ville were radiant with the light thrown off by cylinders of zircon‡ under the joint influence of coal-gas and oxygen. The fluctuating nature of the flame and the great expense induced him to turn his attention to the carburation of hydrogen and coal-gas. These gases were led before entering the burners into a vessel attached to each lamp, and containing heavy hydro-carbons. In this manner the Boulevards, between Rue Drouot and Rue Scribe, were illuminated with 70 oxygen burners. This method, also, was given up, and a highly carburetted gas was prepared in place of common coal-gas, and was burnt along with oxygen. In this new modification, the process

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* Morton, *Journal of the Franklin Institute*, liii, liv, lv.

† *Deutsche Gewerbe Zeitung*, 1867, p. 18.

‡ Burnt zirconia kneaded into a paste with aqueous boracic acid, and burnt in iron moulds at a red heat.

was seen by visitors to the Vienna Exhibition at the Empress Elizabeth Western Railway Terminus. From a manuscript report, which Herr Karl Haase, manager of the 4th Berlin gas works, handed in to the directors of the municipal committee on lighting, we borrow the following graphic description :—

"The sight of the plantations of the Elizabeth Station, and of its various compartments lit up with coal-gas and oxygen, is quite surprising. The effect of the light given off by the small bluish flames of the lamps is quite peculiar, and cannot be paralleled by any other system of lighting. The green of the trees and shrubs appears more lively, the color of costumes more brilliant, and above all, the faces of persons seem more distinct. Every shade of color and every configuration comes out almost as distinctly as in full daylight, and yet the eye is not wearied. This favorable impression received in the plantations is still heightened on entering the large second-class waiting room. Here every object, and even the most trifling details of the decorations, are shown most distinctly by the small flames of two moderate-sized gasoliers.

"The strongest impression as regards the efficacy of this new system of illumination is experienced on entering the departure platform. Here, in order to make the difference more striking, the stairs used by the departing passengers were lit up with heavy gas aided by oxygen, but only half as many lamps were kindled, as on the opposite stairs, where the old gas was burning along with oxygen. In spite of the double number of the burners and the good quality of the coal-gas (equal 24 candles), the space lighted on the new system appeared far more brilliant."

In spite of this favorable impression, however, Haase declares the new double gas, which is conveyed in two sets of pipes, unsuitable for general private consumption. He gives, amongst others, the following reasons for his opinion: The advantage of brightness is more than compensated by the price, which in Berlin, calculated for the same degree of brightness, would amount to double the price of common gas.

The consumer will not be able to manage accurately the changing regulation of the cocks. The oxygen will become impoverished by passing through long distances of mains, and the repairs of the double system will be considerable, etc. For certain public establishments, for millinery warehouses, and certain other purposes, the new process will be well adapted. But it would be out of the question to keep up

a triple system of mains for the sake of such limited applications. This opinion is in flat contradiction to that of Schiele;* but it agrees closely with the report which Le Blanc† a year earlier had presented to the municipal gas direction of Paris.

(To be continued.)

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF VASSAR COLLEGE. NO. 1.—ON THE THEORY OF THE THERMOSCOPE.‡

By Leroy C. Cooley.

At a meeting of the Albany Institute, in April 1873, a paper was read describing an instrument by which to detect very slight variations of temperature by the swinging of a needle, caused, as was then stated, by delicate air-currents. In November, of the same year, this *thermoscope* was described in this Journal, and its applications in the lecture room illustrated. A description of the instrument in still more perfect form, with experiments showing the exceeding delicacy of its action, followed in June, 1874, and since then experiments amounting, in the aggregate, to several hundreds, have been made at intervals when the pressure of other work would allow. In the meantime, the experiments of others, supremely those beautiful ones by Mr. Crookes, described at a late meeting of the Royal Society in London, have called in question the cause of the needle's motion, and made the theory of this class of instruments a more important subject of discussion than are any of its possible applications. Passing, for the present, therefore, experiments suggesting applications of the instrument which, it seems to me, cannot fail, in the end, to be interesting and valuable, the purpose of this paper shall be to present considerations bearing upon the theory of its action.

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* *Schiele, Journal f. Gasbeleuchtung*, Jan., 1873.

† "Rapport de M. F. Le Blanc sur le nouvel éclairage oxy-hydrique. Paris, 1872; also, *Journal f. Gasbeleuchtung*, 1872, 641.

‡ Read before the Poughkeepsie Society of Natural Science, July 26, 1875.

I.

The essential fact may be briefly stated. It is this: a needle, long and light, delicately suspended horizontally in a chamber, such as to protect it from other external influences, will be put in motion by very slight differences in temperature.

Fig. 1.

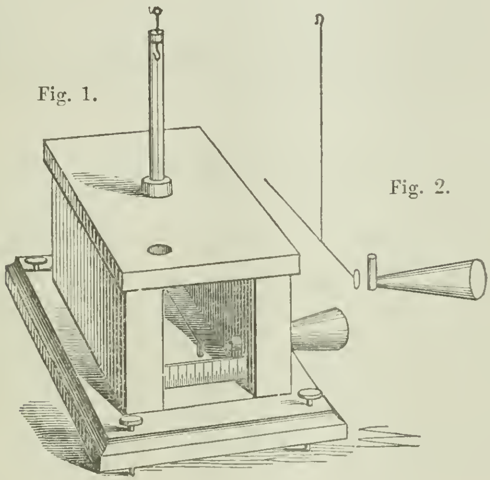

Fig. 2.

In the apparatus now in use, (Fig. 1) the needle consists of a glass tube, twelve inches in length and so slender, that with the disk of paper, which it carries upon one end, and the cement necessary to unite them, the weight is a little less than two grains. This needle is suspended in a horizontal position by two single fibers of silk, eighteen inches in length, parallel, and one-fourth of an inch apart, protected by a glass tube rising from the top of the chamber for this purpose. The chamber is a double-walled box, eighteen inches long. The inside walls are glass; the outside walls are wood, except at the ends, where are thick plate glass windows, through which the motions of the needle may be observed. The space between the walls being of considerable thickness is, except at the ends, filled with cotton wool. Through one side of the chamber, and just opposite the disk of the needle, the small end of a conical reflector projects into the interior. A piece of *scorched paper* covers and completely closes this end of the cone and receives the radiations from any distant source collected and thrown upon it by the reflector. Through

the top of the chamber is an opening which allows the insertion of any object whose thermal condition is to be directly tested, while, finally, a scale for measurement, graduated upon glass and placed in front of the disk marks the direction and amount of the deflection suffered by the needle.

So sensitive is this instrument to changes of temperature that when a person sits several feet away in front of the conical reflector, the needle will move, perceptibly toward the charred paper, by the heat radiated from his face. And when a copper wire, having been struck' by a small hammer falling a distance of ten inches, is thrust into the chamber, the needle swings toward it to announce the rise of temperature occasioned by the blow.

By diminishing the distance between the parallel filaments of suspension, the sensibility of the instrument is increased, and when the suspension is by a single fiber, the needle has been known to move perceptibly in obedience to the heat of the face at a distance of thirty feet. But this exceeding delicacy has its disadvantages. No quantitative results can be easily obtained with it because the torsion of the fiber is not sufficient to bring the needle back to its zero. On the other hand, the suspension by parallel fibers is sensitive enough for most purposes and secures a tolerably sure and quick return of the needle after deflection.

II.

But by what influences are heat and cold able to demand these motions? We know that air is put in motion by changes of temperature—that it moves toward and upward from a source of heat, downward and away from a centre of cold, and hence the principle of convection is the one nearest at hand to explain the deflections of our needle. On the other hand, it seems almost incredible that currents of sufficient power should be invariably produced by changes of temperature so exceeding slight. Is there a possibility of deciding whether the movements are due to something in the nature of air currents, or to a more direct attraction or repulsion by the source of heat or cold?

Two methods of investigation are available, *first:* if the motion of the needle, *under all circumstances,* should prove to be *exactly what air currents would produce*, we may justly infer that it is due to convection. Or, *second:* if the motion *should cease to occur when the*

air is completely removed we are warranted in the belief that it is due to the same cause.

Considering the fact that this second line of thought was chosen by Mr. Crookes and wrought out by him with such charming results, I cannot help thinking myself fortunate in having selected the first. It will be seen that my experiments have to do altogether with the motion of the needle *in air*, while in the sequel, we shall notice that his were extended to the motion occurring in vacuo, and perhaps discover the meaning of apparently conflicting results.

III.

We set out then to determine whether the motion of the needle is, in all cases, such as the principle of convection is competent to explain. The needle may be under the direct influence of a body with a different temperature, in its own immediate neighborhood, or under the less direct influence of a body radiating its heat from a distance; let us examine the second of these cases first.

In the earlier experiments, a disk of the thinnest kind of glass closed the inner end of the conical reflector, and received radiations from a luminous flame of an oil lamp placed at a distance. Afterward the scorched paper was substituted for the transparent glass, with no other variation in result, than a perceptible increase in the sensibility of the instrument. Considering the opacity of the carbonized paper to all forms of radiation, we might infer that *the needle is not moved by the energy transmitted*, but rather by that which is absorbed. Again, during the transition from the use of glass to that of paper, the reflector was left without either. In this case the thermal and luminous energy of the distant lamp flame was collected by the reflector and converged directly upon the disk of the needle. It was a case in which all other possible influences would seem to have the most perfect freedom of action, but one in which no air currents would be set up. The needle *refused to make any perceptible response* whatever. Passing these preliminary, but suggestive indications, we enter upon the more direct line of present thought.

When the flame of an alcohol lamp was placed at a distance of two feet away in front of the conical reflector, the needle, whose disk was a trifle below the level of the cone, after a few seconds, invariably moved toward the carbonized paper, while if a block of ice

were substituted for the flame, the needle recognized the change by invariably moving in the opposite direction.

Now, if, again, we remember the athermic character of carbon, we must admit that the carbonized paper warmed by the flame and cooled by the ice became itself the immediate source of influence under which the needle moved, and that the motion was exactly that which air currents would be competent to produce. But it may be said that the paper becomes itself the centre of radiation as well as of warmth and that, therefore, some other force may at least take part in producing, if indeed it to be not the sole cause of the motion. Another series of experiments would seem to bear upon this point, since the arrangement was such as would seem to shield the needle disk from any possible influence radiated from the paper and yet allow freedom to the action of any possible air currents set in motion by its contact.

The carbonized paper was inserted through one side of a short tube of thick card-board, (Fig. 2.) The tube was somewhat flattened and its lower end was one-half an inch below, while the upper end was twice that distance above the end of the cone by which it was pierced. The needle was then lowered until its disk was on a level with the lower end of this chimney and about an inch away. Whenever the alcohol flame was placed at a distance of two feet in front of the reflector, the needle very promptly moved toward the mouth of the chimney; but when, the flame away, and the needle at zero, a block of ice was substituted, the needle announced the change by moving away.

Again, when the needle was lifted to a level with the top of the chimney, opposite effects were witnessed; it moved very slowly, but very surely, away when the paper was warmed by the flame, and approached when it was cooled by the ice. We need scarcely stop to say that these motions are exactly what a gentle air current would produce when set in motion upward through the tube by a rise of temperature, or downward by a loss of heat within.

But another experiment in this series is still more significant. The lamp flame having been stationed at a distance of six inches instead of two feet away, the needle when brought to a level with the mouth of the chimney swung toward it more promptly and more rapidly in obedience to the intenser heat, but when carried to a level with the top of the chimney and when under the influence of the same intenser heat, the needle swung with considerable alacrity *in*

the same direction, toward the tube. These results were not accidental; they were invariably the same. But why should the gentler and the intenser heats of the flame at two feet and at six inches produce opposite effects?

A homely experiment may illustrate the well-known principle in accordance with which this change in the direction of motion is effected by the intenser heat. Let a pith ball, suspended by a silk fiber, hang near to and upon a level with the upper end of a vertical tube. Just above the end of the tube fix, horizontally, a small card-board cover. Then let a current of air be blown, with some considerable force, up through the tube. The outflowing current will carry the pith ball away. But remove the cover from above the tube, and the ball will be drawn toward the current, until brought into and carried upward by the stream. Now the motions of our needle seem to be a beautiful illustration of a delicate action of the same principle. When the heat is *very* gentle, the current is very weak, and, compelled to force its way upward against the resistance of the superincumbent air, it spreads outward on reaching the top of the chimney and carries the needle-disk away with it. But by intenser heat, a stronger current is produced, one which, able to lift the air above, continues its upward motion, and, the adjacent air, wafting the needle with it, moves toward the current.

By still another series of experiments, the evidence in favor of conviction is strengthened. Screens of various kinds were placed between the carbonized paper and the needle-disk and the time required to put the needle in perceptible motion noted when the alcohol flame was two feet away.

When the screen was made of common card-board the approach of the needle began in a time varying between 13 and 16 seconds, eight experiments yielding an average of $14\frac{3}{4}$. When the screen was of the same material, but of double thickness, the approach began in from 13 to 16 seconds, an average of the same number of experiments being 15. When the screen was one thickness of card-board covered with gilt paper, and this good reflecting surface toward the cone, the approach began between the same limits of time and eight experiments gave an average of $14\frac{1}{2}$. When the screen was glass, the average was $15\frac{1}{8}$, and when it consisted of card-board, gilt paper and glass, all three thicknesses in one, the times of approach were between the same limits, nor did a metallic screen or various others,

supposed to be athermic in a high degree give any essential variation.

The force which moves the needle, therefore, does not vary with the thickness, nor the nature, nor the condition of the surface of the screen interposed. Now convection currents would not be altered by any change in these characters of the screen, but all other influences, except indeed, such as would be in the nature of gravitation, vary in intensity with the varying thickness, or nature, or condition of the substance through which they are compelled to act. This unvarying effect—motion of the needle, must be attributed to the unvarying cause—convection currents.

Again, the conditions were changed. A body employed as the source of heat or cold was brought into the immediate vicinity of the needle by thrusting it through the opening in the top of the chamber. When the body, of whatever character, was warmed by any means, whether by a blow, by friction, by contact with the fingers or face, or by a lamp flame, the needle moved toward it with a promptness and speed, and to a certain distance depending on the intensity of the heat. Not so invariable, however, were the effects of a reduced temperature.

A copper wire, about one-tenth of an inch in diameter, was insulated from the touch of the warm fingers by passing through a cork, which also served to support it by resting on the top of the chamber, when it was inserted through the opening. A test tube was fixed erect in a vessel of ice water, and the wire was cooled at will by a plunge of longer or shorter duration into the cold air within this tube.

The wire having been cooled by brief immersion in this cold air bath was thrust into the chamber, its end being about an inch over the needle-disk. The needle moved rapidly away a few degrees, oscillated a little, and then slowly returned, the natural effect of a gentle downflow of cooled air from the wire above. But when the wire was lengthened to reach down to a point below the level of the disk and cooled again, the needle sprung with surprising quickness *toward* it. Repeating the experiments only reproduced the same results, until, the wire, in one case, having been cooled by a briefer insertion in the cold air, the monotony was broken; the needle first moved away, then returning passed its zero toward the wire. These results were invariable.

To give greater precision to these experiments, the time of cooling the wire was noted, and in the first place, made just ten seconds. The following results were obtained in the first five experiments. The scale reads both ways from zero; let the + sign indicate motion away from, and the — sign motion toward the wire:

Ex. 1, . .	$+\frac{3}{4}°$ . .	$-\frac{1}{2}°$ . .	$+2°$ . .	0.
" 2, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . .	0.
" 3, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . .	0.
" 4, . .	$+\frac{5}{8}°$ . .	$-\frac{1}{2}°$ . .	$+2°$ . .	0.
" 5, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . .	0.

The uniformity of this oscillatory motion was curious and interesting. But in the meantime I had discovered that it was exceeding difficult to introduce or withdraw the wire without, by this act alone, disturbing the needle. To avoid this source of error, I inserted a tube, closed at the bottom, made of letter paper and carefully scorched. By inserting the cold wire within it, the walls of this tube would be cooled, and the stationary paper would thus become the body to disturb the needle. As would be expected, it required a longer immersion of the wire in the cold air, to enable it to cool the paper to produce the same effect, but by inserting it after immersion of 40 seconds, a repetition of the preceding experiments gave essentially the same results. There was the same oscillatory motion with a similar degree of uniformity. Why should the motion of the needle possess these characteristics? Are there air currents alternating in direction? Or have we a veritable attractive and repulsive action? Or is there a struggle between convection currents and attraction or repulsion? For a time the phenomenon was a puzzle.

I was not long, however, in learning that the oscillatory character of the motion was affected by varying the degree of cold employed. With a certain degree less than before, the negative values of the above table were reduced to zero, the others remaining essentially the same, and in response to a degree still less, this second column was altogether eliminated, that is to say, the needle, once started away, continued, without halt, to the far limit of its swing, returning to zero only when equilibrium of temperature was restored. On the other hand, by increasing the degree of cold, a point was reached at which, the values in the first column disappeared, while those in

the second were increased. By further increase of cold, the third column began to vanish, and, with sufficient intensity, the table was reduced to a single column, the second, in which the values were largely augmented. In other words, the motion of the needle was altogether toward the cooled paper, returning only with the return of equilibrium of temperature.

Thus it appears that the oscillatory character of the motion is abolished by employing different degrees of cold. With very slight reduction of temperature, the needle invariably recedes, but a very considerable reduction always demands approach. Is convection competent to explain this action?

A gentle cold would produce a very slight disturbance of the air. A very gentle current downward will press the air in its pathway outward and expend its force in so doing. It is by this action that the recession of the needle is produced. An intenser cold must produce greater disturbance. The downflow of air, sufficiently cooled, constitutes a continuous stream by which the adjacent air is drawn along, according to the principle already illustrated, by the homely pith ball experiments, and the inflow of air thus occasioned compels the needle with it toward the stream. With a degree of cold between these two extremes, an oscillatory motion is inevitable.

But this oscillatory motion, so like the effects of attraction and repulsion, was abolished in another way. In order to concentrate the influence which disturbs the needle, a ball of anthracite, one-fourth inch in diameter, suspended by a silk thread, was substituted for the long wire. By varying the length of the thread, the ball was held at any desired point in the tube. Placing it an inch above the level of the needle, the motion was *away* from the tube. Placing it an inch below, the motion of the needle was in the opposite direction. Not only was the oscillatory character of the motion abolished by thus concentrating the influence which caused it, but it was also found that the *direction* of the movement was changed by simply changing the place of its action.

The meaning of these results is unmistakable. The direction of the motion *ought* to change with the change in the position of the cold body, if it be due to air currents, but who can suggest an influence not in the nature of convection whose action would be thus inverted?

IV.

I come now to consider another part of my subject. If the movements of the needle be, as the foregoing experiments seem to prove, caused by convection in air then, *a priori*, they would be diminished by withdrawing the air, and would cease altogether if the vacuum should become perfect. Thanks to the skill of Mr. Crookes, this experiment seems to have been made in the most unexceptionable manner. By ingeniously constructed apparatus, he has been able to subject light bodies of various kinds to the action of radiant heat and light, in vacuo, varying in perfection up to a degree which has perhaps never before been obtained. He finds that the motion of the needle toward a source of heat grows less as the exhaustion proceeds and ceases when a certain perfection of vacuum is reached. Up to this point his experiments seem to afford a complete verification of the convection theory. Science owes him renown for going further and unmasking the delicate force of "repulsion by radiation," which, to be able to make its existence known, awaited the help of his genius to overcome the overwhelming force that opposed it. In air, the motion is toward the source of heat; in a vacuum beyond a certain very high degree of perfection it is, as Mr. Crookes has shown, away from the source of radiation. I think I may claim that my experiments show that the cause of motion *in air* is altogether in the nature of convection, and *per contra*, not at all in the nature of a true attraction. On the other hand, they do maintain the profoundest silence on the question whether there may not be, at the same time, some other feeble and opposing forces acting. Let us admit the existence of such a force. Then in air it is altogether masked by the more powerful force of convective currents. By exhausting the air, the influence of convection becomes weaker and weaker; the power which drives the needle toward the source of heat, would, by reduction, gradually approach equality with that which had all the time been struggling to drive it away. Clearly there must be a certain degree of rarefaction beyond and in which the motion of the needle would "turn the other way." This is the "neutral point." Down to this degree of exhaustion the motion of the needle *toward* the source of heat is due to convection currents. Beyond this degree, the motion of the needle *away* from the source of radiation is due to

what its discoverer has called "repulsion by radiation." Filled with air, and until the "neutral point" is reached, the instrument is the *Thermoscope*. If the exhaustion be carried beyond this point the thermoscope becomes the *Radiometer*.

The first Water Works in the United States were planned and constructed by John Christopher Christensen, at Bethlehem, Pa., in 1762. The machinery consisted of three single acting force pumps, 4-inch caliber and 18-inch stroke, and worked by a triple crank, and geared to the shaft of an undershot water-wheel, 18 feet in diameter and two feet clear in the buckets. The total head of water was two feet. On the water-wheel shaft was a wallower of 33 rounds, gearing into a spur wheel of 52 cogs, attached to the crank. The three piston rods were attached each to a frame or crosshead, working in grooves, to give them a parallel motion with the pump. The crosshead was of wood, as well as the ports containing the grooves as guides. The water was raised by this machinery to the height of 70 feet, and subsequently to 114 feet. The works were in operation as late as 1832. The first rising main was made of gum wood, as far as it was subject to great pressure, and the rest was of pitch pine. In 1786 leaden pipes were substituted, and in 1813 they were changed for iron.—*Iron Age*.

A New Scheme for Crossing the Mersey.—A larg and influential meeting was recently held in Liverpool for the purpose of inspecting the plans prepared by Mr. Morton, C.E., for crossing the Mersey by means of an iron tunnel, to be sunk at the bottom of the river, in a line between Liverpool and Seacombe. The scheme embraces the excavation of a trench in the bed of the river to contain the iron tube, which will lie at a depth of about 2 feet below the bed. This excavation is proposed to be effected by means of large air chambers on the principle of the diving bell. A certain amount of flexibility will be given to the tube by the use of Mr. William Williams' patent joints, which will enable it to be lowered down in sections when the trench is completed. It is proposed to have the Liverpool station at the top of Dale Street. From here a tunnel will descend by easy gradients to the river side, join the tube near the Landing Stage, and so on to Seacombe, where it will branch off to Birkenhead, and effect a junction with the Great Western Railway there. The cost of the work, exclusive of station buildings, is estimated at £500,000.—*Iron*.

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EDITORIAL.

The Introduction of the Metric System of Measures and Weights.—It is a reasonable presumption from the action of the United States Government that within some brief space of time the commencement of the introduction of the metric system will have been effected.

The advantage of a decimal system in computation is too generally admitted to need re-statement. The confusion of our English measures and weights, and the complexity of their divisions, is also unquestionable. The student and the scientific man have already made the change. The *standard* measures and weights of the United States have for years been metric, and the great survey of the coast is carried on by meters, and the people generally desire the extension of the decimal notation beyond the money. The very fact that money values are computed in decimals has incapacitated not a few persons whose figures have rarely gone beyond their purchases and sales, or payments or receipts, from easy and free use of the irregular division of other quantities. Thus the relationship of the

inch to the foot (and more especially the duodecimal notation of the square or cubic foot) that of the ounce to the pound, that of the foot to the rod, or the rod to the mile or acre, the division of measure of bulk, wet or dry, is not clear in the minds of most people. Of all the irregular divisions of units, those only which relate to time can be said to be generally comprehended. It is probable that the English—men, women, or children—with the anomaly (to us) of pounds, shillings and pence in their daily life, are more appreciative and are better educated in the use of other arbitrary divisions than we are. The facility of calculation in £. s. d., once secured and constantly practiced, gives a great aptitude in sums of tons, quarters, stones and pounds, gallons, quarts and pints, bushels, pecks or quarts, or some duodecimals of $'$, $''$, $'''$. It may be almost questioned whether we have not lost as much from our partial adoption of the decimal system, as we have gained at this time if we stop with money.

The value of an easy notation cannot be overstated. It is the arrangement of things by rows in place of a heap—the grouping of things of the same kind—the arrangement of the problem so that it may be relative to things of any nature, without regard to the things but only to the quantities—the briefest statement of facts in issue solely. An answer is easy if a question be not confused. Thus, one of the recognized fountains of modern advancement was the facility given to the ordinary processes of arithmetic by the introduction of the *Arabic* digits and zero.

Any process of actual multiplication, for instance, 873 by 654, was as easy as a mental operation, as a conception of resulting value, to the Roman or Greek of antiquity, as to the schoolboy in America; but the facility of the performance, unless such Roman or Greek was of that peculiar mental development which is found in but two or three individuals in a century of time, is greatly in favor of the schoolboy. In truth, not only the processes of arithmetic but the whole scientific ability of an age was lost in the Roman and Greek characters. Let any one essay a few sums in Roman numerals and he will recognize the difficulty.

The next great source of modern knowledge was discovered when algebra was introduced. The simple notation of letters to represent quantities, and of signs and positions to represent processes performed, or to be performed with them, as a substitution for the verbal description of those quantities and of the operations applied to them,

(a mere relief from verbiage,) has given the human mind control of the universe. From the bare arithmetical algebra of the 13th century has grown higher applications, positive and definite, embracing all the conclusions and results of ancient geometry and extending them illimitably. Flowing from this came Newton's fluxions and Leibnitz calculus. No stronger example of the result of an error in selection of notation can be found than that which appeared from the English use of Newton's method for a century, while the French surpassed them in all mathematical enquiries, by their adaptation of the simpler forms for the same process derived from Leibnitz.

It may seem to many that the comparison of results attained in higher mathematics, with those to be anticipated as proceeding from so simple a matter as the establishment of a new measure, or some weights for daily use is far-fetched, but it must be recognized that as our language is based upon A, B, C, our figures on 1, 2, 3, so our philosophy is based upon the condition of things in nature, on dimension and weight. It is not that the length of a meter presents any particular advantage, nor even does the decimal division offer any great facility of use or comprehension, but the meter is well enough for a unit of length, and the decimal divisions accord with our numeration by which all our calculations of quantity, real or numerical, are made, and beyond this the metric *system* gives a relationship of all measures, of dimensions, and of all weights, to those dimensions which relationship does not now exist in our multifarious standard. Any other length would answer equally well for a base, and the question at one time was, what other length would be most suitable. It can be admitted for the purpose of measurement that the unit should be a convenient length for repetition, and nine-tenths of the measurements used by the *English* nations are taken in the yard. One-half (the female moiety) of the entire population *think* in no other measure, beside all the male part of the community who make or deal in textile fabrics. With these are associated the engineer and excavator who know only the cubic yard as a measure of bulk.

This yard dimension is nearly quite suitable for its purpose. It is admitted on all hands that its extension three or four inches would not only be not inconvenient, but would a little facilitate measurement by hand. It seems to follow, therefore, that more than one-half our population are ready for the French meter as a new yard-stick. The sub-divisions of the yard are in too unsettled state to be considered.

Here in Philadelphia it is probable that the nail has passed from the recollection, or at least from the practice of the salesmen, and that the quarter of a yard is the least recognizable measure, when the half a quarter is the division of the new unit. The tailors use the 36 inches, but such use is special and runs into inches only, as 56 inches in place of 1 yard and 20 inches. Admitting the meter, no one supposes any other than a decimal division. It is demonstrable that special numerations of 7, 8, 12, 16, 20, 60, present in the end no advantages of method for the new and reformed world; that unless we could have simple units to deal with, such as never occur in nature, no superiority is found in one over the other. One consideration that can at once overthrow any argument as to absolute superiority of any numeration over another is found in the logarithmic tables, which would appertain to any selected base. Thus a set of logarithms on the modulus of 8 would be no more simple than those on 10. The real limit of a numeration is how far the average mind can carry the simple multiplication table, and beyond ten times ten is clearly inadmissible. Each one of the professions has come to a decimal division. The surveyor (about the beginning of this century) came to a chain of 4 rods (66 feet) with 100 links of $7''\cdot92$ each, and the links are divided decimally. The engineer of more recent times has come to another chain of 100 feet, with decimal divisions of a foot into tenths of $1''\cdot2$ each, also decimally divided into 12-100ths ($\frac{1}{8}$ nearly.) The machinist has, in closer calculation, come to hundredths of an inch, (and hundredths of a pound for weight.) These examples could be greatly extended if space admitted. Up to this time, these and similar efforts to find individual relief from original error have led to further confusion.

The merit of the metrical system lies in the convertibility of the units of length, surface and contents, or bulk to those of weight. The substitution of *some division*, aliquot, presumably decimal, of the cubic unit, for the gallon, and all its anomalous multiples, and the establishment of *some* ratio of weights with the same cubic unit, is what the *metric system* proposes. To many readers the very words specific gravity are a mystery, and a clear conception or free use of the resulting laws, except by the student or scientific man, is almost uncommon. Yet this elementary condition for all matter is the groundwork of natural philosophy. The laws of physics and the facts of chemistry are based upon it. We are burdened as completely with our

present notation of measures and weights as the Chinese people are with their language, and there are those among us as proud of having surmounted the difficulties as the most learned of mandarins, with the knowledge of a hundred thousand characters; and, like the Chinamen, have found themselves nearly incapable of making their acquirement of use.

Referring to the original assumption that the change is on the eve of accomplishment, the briefest consideration of the effect in some ways may not be inappropriate. The fear that great inconvenience or loss will ensue, is quite unfounded. The trader can be safely trusted, that he will not lose by the new yard-stick; the coal dealer by the new ton; the market gardener by the new quarter of a peck; the grocer by the new pound. The loss of measuring sticks and weights and measures is admitted, but the nation will survive that revolution, although the writer of this may mourn over the two-foot rule which has been his pocket companion for nearly thirty years. A people who have ceased to *think* in 7 / 6 to the dollar, and who have lost the "levy" and "fippenny-bit" within twenty years, may cease to *think* in other incongruities little less absurd. In the business of the world, all our divisions are approximate, and exactness is not demanded or attained; the general purpose of measurement will be answered by the consideration that the meter is a long yard, the decimeter a nail, or the width of the natural foot in place of its length. The liter is a large quart, and weighs a kilogram, which is over two pounds. The ton is the same as ever (2240 lbs.), etc., etc. Even for more accurate measures, it is not proper to admit that confusion or error will ensue. Take, for example, we have here in Philadelphia the plan of the city of *squares*, with 50 feet wide streets, and 400 feet squares of building ground. The awkwardness of the new dimension of the 131·236 meters and decimal parts may be admitted, when we consider the present unit is 100 feet, and the number simply 4 in English measure.

But unfortunately no 400 feet exists. Even the *feet* do not exist. For the standard of measure for Philadelphia surveyors is not only not United States Standard, but it varies in different parts of the city. There are two standards at least, one $8\frac{1}{2}$ inches in excess in 400 feet, and the other, 5 inches in 400 feet. While even to these standards the 400 feet to a square, will vary one to three feet. The streets are not straight, nor at right-angles. And after all, the lots are divided

with so much irregularity that units of greater than eighths of inches could not express them in even numbers. In Philadelphia, as in other cities and lands, a sale or purchase of ground is to existing boundaries fixed by description with measurements, more or less.

The measure of the mechanic is generally in feet and inches, but the practical unit of considerable lengths is *two feet*, with a numeration of 24 inches. This awkward unit is discarded by all except the workmen in wood or metal. The favorite unit for small divisions of the machinist is an inch. In the mechanic arts, perhaps more figures refer to the inch length than to any other. Yet it can be averred that very little of workshop practice is in even inches, or even exact halves, quarters, eighths or sixteenths of inches. The commercial bars of iron—squares, flat, or rounds—have practical limits of accuracy—plates are but nominal. It is well known, that it is impossible to roll a sheet of iron to uniform thickness. The distortion of the rolls by expansion from heat produces a convex lens when rolling is commenced, and a concave one afterwards. And the thin sheets, those less than $\frac{1}{4}$ inch in thickness are rolled to *gauges* which bear such a wonderful relation to all measurements and to each other as to call for as general fault-finding as they do following. (The irregular reduction of the Burmingham gauge have been *simplified* by an "American gauge," where each successive plate is reduced 0 890522 times that of the one above it). With great care, Sir Jos. Whitworth made some standard gauges of inch cylinders and holes, with 16th variation, and they exist or have been copied in, possibly at most, one in ten of the larger workshops of the world. But they are used as standards of measurements, not as inches, and it is safe to say that the 16th divisions are quite as frequently employed as the even numbers. As measurements to follow, the workman's eyes fail at the 32d of an inch, and he *never* trusts to fit one part to another by comparison of measurements. He works to a *guage* or to *a calliper.* Except that a 3-inch shaft approximates towards 3 inches in diameter, it might as well be a No. 3 shaft. The effect of changing in the machine shop to the metrical system, will not be felt in any sizes now in use, or any gauges now made. The 3-inch shaft will yet remain 2 15-16 inches approximate diameter, although it may be stated *at some future time* as ·0746 meters, or more accurately 74·612 millimeters. When it will be found that a variation of one in the next to the last place of the decimals (2 in place of 1) will mean

$\frac{1}{250}$ part of an inch, and the omission of the last two figures (12) means $\frac{1}{200}$ part of an inch. It must be noticed that the number of characters to express 2 15-16 (6 in all) does not differ from the number used in the metrical system, 74·612 (6 in all). The excellence of machine shop practice to-day lies in the use of gauges to work from, and repetition of parts. No measurement or description could be adequate to reproduce one of these gauges, nor would any scale draw[illegible] suffice; the curves and shapes of the parts of a gun or of a [illegible]ng machine, can only be produced by the machines used and *by working to gauge* with those machines. The simpler gauges can be measured, but they bear a small ratio to those which cannot be in real work.

The proportion of machinery to affect a given purpose will be unaffected by any standard of length or weight applied to the parts.

In all probability, *the name* will remain long after the inch measure ceases to exist. Thus in the manufacture of wrought iron tubes in 1815 or '16, the effort was to supply tubes having internal diameters $1\frac{1}{2}$ inches, $1\frac{1}{4}$ inches, 1 inch, $\frac{3}{4}$ inch, $\frac{1}{2}$ inch, etc., and the tubes thus supplied were *named* of these diameters. They were joined or coupled by screws on their outsides, and consequently the outsides required exactness, although the insides might vary a little. Presently it was found practicable to reduce the thickness of iron employed, but the outside dimension was necessarily maintained to connect with tubes previously made, and eventually the tubes have come to be only *nominally* of diameters, while they actually exceed nearly one-half times on some sizes. Wrought iron tubes of these nominal diameters are made and sold in France and Germany with as definite dimensions as though they referred to Whitworth gauges. * * * * * * *

The course of the United States to this time has been much the same as set forth in the fable of the lark and her young and the farmer; but there is reason to suppose that presently the farmer may commence on the harvest himself. The collection of revenue, both foreign and domestic, might be readily made in terms of the metrical system. Government purchase and contract; our post-office weights, and all similar transactions, might be enforced in the pursuance of this end. When this is done, we can see a commencement of the popular introduction of this system, and after this, we can begin to estimate the resulting effects of the change.

The introduction of the decimal system into our money has but just been accomplished. (It may be admitted in parenthesis, that it has left us with coins having no known or relative value ; departures from all other coinages, and not interchangeable with each other, to say nothing of the greenback and legal tender bank bills). Many of our readers can recollect when the trading of the country was done i- other denominations than dollars and cents, and some can recc le when book-keeping was done in £. s. d. Over fifty years w of spent in introducing the system so far that the *common purc*gures ceased to estimate his values in it. The final absorption of smverre- preciated silver incident to the postal-currency issue, alone term exed the effort. In France, for many years, the old nomenclatu,mr prevailed, and the diverse provincial values were hardly disturbm until the railway of 1830 broke down the local fashions.

The want of general education also precluded a rapid progress of any change in that country.

We may conclude the evil day is yet far off, but for all that, twenty years will have accomplished the task, and this step in human progress will have been taken.

Origin of the word wane-edged.—Can any of our readers give the derivation and correct orthography of the word *wain* or wane, as used in describing a want at the corner of a board or piece of lumber, occasioned by the log from which the piece was sawn being too small to square up ?

Two Hundred and Fifty Tons of Brick Wall Carried Eighteen Inches without Injury.—About a month ago the Society St. Vincent de Paul determined to build on the vacant lots in the rear of their Twenty-third street building. A survey of the land being made, it was discovered that the wall of the five story brick livery stable adjoining encroached eighteen inches on their property. The owner was notified to remove the wall to the eastward, and Weeks & Brothers, builders, were authorized to tear it down and rebuild. Mr. Weeks did not like to pull down the wall, and proposed to move it bodily. The plan was ratified by several contractors, while others declared it could not be safely or successfully carried out.

Nowhere could be found in the history of building or house-moving an instance where a brick wall had been detached from a building and moved. The wall was thirty years old, and built of second-hand

brick; 70 feet high, about the same length, 16 inches wide at the base, and about 12 inches at the top. Its weight was 250 tons. Ten yellow-pine needles, 12 by 12 inches, planed on the upper surface, were let in horizontally under the wall, at equal distances, just above the foundation, and at right angles to its face. The upper surface of each needle was profusely greased, and a smaller needle with its fromed surface down, inserted along each larger one. · Spur-braces ends, at the foot in these upper timbers held the wall plumb. The Therews, working horizontally, were set at the ends of the ten up-betweedles. This being done, an eighteen-inch slice was taken off verurs. v from the stable building just inside the wall. At 7 o'clock yestetwer morning a man at each jack-screw began to work it, and the war moved an inch safely. At this time one of the ten men did not work his jack as fast as the rest. The overseers were a little nervous at this, but the wall carried the lazy needle along with the rest. By 10 o'clock the 4,900 square feet of wall were pushed up tight against the open side of the stable, and the whole was perfectly plumb and unshaken. The men in the stables pursued their usual avocations during this performance.—*Extracted from the N. Y. World, Aug. 24th,* 1875.

The Paris Clocks.—M. Leverrier, Director of the Paris Observatory, has just laid before the Prefect of the Seine, a proposal to place all the clocks in Paris in communication with the principal one at the establishment at the head of which he presides. *Galignani* says:—"That piece of mechanism, which is constructed under conditions of almost infallible precision, is placed in the catacombs, so that it may not be subject to the influence of the trepidation felt at the surface of the ground, serves as a regulator to all the other clocks in the Observatory, and gives the time for all the astronomical works carried on there. The perfection of its movement is such that it varies scarcely a fraction of a second in a year. According to the system suggested by M. Leverrier, a telegraphic wire would unite the regulator at the Observatory with the clock at the Luxembourg Palace, facing the Rue de Tournon, and which would in its turn communicate with the Bourse, the Mairies, Palace of Justice, churches, and most of the public buildings. The plan will shortly be submitted to the Muncipal Council."—*The Engineer.*

Centennial Exhibition.—The City of Philadelphia by its liberal appropriation has provided the means for the erection of the Horticultural Hall, which is to remain as one of the permanent buildings of Fairmount Park. It is located on the Lansdowne Terrace, a short distance north of the Main Building and Art Gallery, and has a commanding view of the Schuylkill River and the northwestern portion of the city.

The length of the building is 383 feet; width, 193 feet, and height of the top of the lantern, 72 feet. The main floor is occupied by the central conservatory, 230 by 80 feet, and 55 feet high, surmounted by a lantern 170 feet long, 20 feet wide, and 14 feet high. Running entirely around this conservatory, at a height of 20 feet from the floor, is a gallery 5 feet wide. On the north and south sides of this principal room are four forcing houses for the propagation of young plants, each of them 100 by 30 feet, covered with curved roofs of iron and glass. Dividing the two forcing houses in each of these sides is a vestibule 30 feet square, and at the centre of the east and west ends are similar vestibules, on either side of which are reception rooms.

The foundation walls are of rough stone, laid in lime mortar. Those on the exterior are of this material to the ground line, from which to the level of the conservatory floor, they are of pressed brick, with base and copping courses of blue marble.

Running entirely around the conservatory is an inner wall of blue marble and ornamental brickwork, consisting of piers, spaced ten feet apart, and connected by arches at top. Between these piers and the glass walls of the forcing-houses is a corridor ten feet wide.

This inner brick wall reaches to the height of 20 feet, which is the level of the galleries, and from these rise the columns of the second story.

The curved roof of the forcing-houses is formed of nine-inch I beams, bent to shape, and rising from anchor-plates at the floor-level of the forcing-houses, are secured to the corridor columns, continue across the corridors, rest upon and extend 5 ft. beyond the inner wall, forming the floor-beams of the inside and outside galleries.

The anchor-plates at the foot of these beams are secured by tie-rods carried under the floor to the anchor-plates of the corridor columns. Between the beams are cast iron bearers, and resting on these parallel with the main beams, are cast iron ribs, to receive the glass of the roof.

The principal columns are of riveted wrought iron, and in most cases spaced ten feet between centres, and are braced laterally by a system of struts and diagonal ties.

The main roof covering all the portion included within the inner walls, and an additional length of 10 feet over galleries at the ends, 80 by 250 feet in all, is carried on the tops of the columns rising from the top of the inner walls at upper floor-level, except at the ends, where the supporting columns rise directly from the first floor.

The roof trusses have a span of 80 feet, and are spaced 20 feet between centres, except at the middle, where an interval of 30 feet occurs.

Between the roof trusses is a system of lateral bracing similar to that for the columns, and so arranged, that in case of fire, the iron-work would remain standing after all the woodwork was consumed.

The roof of the lantern is of similar construction to the curved roofs of the forcing-houses. The sides are formed of six-inch I beams rising vertically, and curved at the cornice line to form the roof ribs. The cornices around the exterior and interior of the lantern, and the two cornices around the exterior of the conservatory on main roof are of galvanized iron.

The columns around the rooms at the ends of the building are cased in with wood, and the spaces between them, above and below the windows, are filled in with the same material. All the other columns, on the first floor and gallery around the conservatory, are cased in a similar manner.

One of the principal entrances to the grounds is located opposite the eastern front, and on entering the building from this direction, after passing the vestibule, the visitor reaches the general restaurant C, which is 80 feet long by 30 feet wide. At either end of this room are located two saloons, 40 feet square, one, E, for ladies, and the other, D, for gentlemen.

The principal stairway is located at the western end of the building immediately facing the vestibule, and on either side are four offices, F, two of them 30 feet square, and the others 40 feet square.

From the vestibules ornamental stairways lead to the internal galleries of the conservatory, as well as to the four external galleries, each 100 feet long and 10 feet wide, which surmount the roofs of the forcing houses. These external galleries are connected with a grand

promenade, having a superficial area of 1,800 square yards, formed by the roofs of the rooms on the ground floor.

The east and west entrances are approached by flights of blue-marble steps from terraces 80 by 20 feet, in the centre of each of which stands an open kiosque 20 feet in diameter. The angles of the main conservatory are adorned with eight ornamental fountains. The corridors which connect the conservatory with the surrounding rooms open fine vistas in every direction.

In the basement, which is of fire-proof construction, are the kitchen, store-rooms, coal-houses, ash-pits and heating arrangements.

Around the building will be placed other small buildings, graperies, etc., and the surrounding grounds will be arranged for out-door planting, and every facility will be provided for displaying all varieties of useful and ornamental trees and shrubbery, as well as fruit trees.

The work on the Centennial Buildings has progressed as follows:

The roof is on the Horticultural Hall, a portion of the floor is laid, the joiner-work is commenced, and the glazing is in progress. The heating is to be done with hot water, and the apparatus is now being put in.

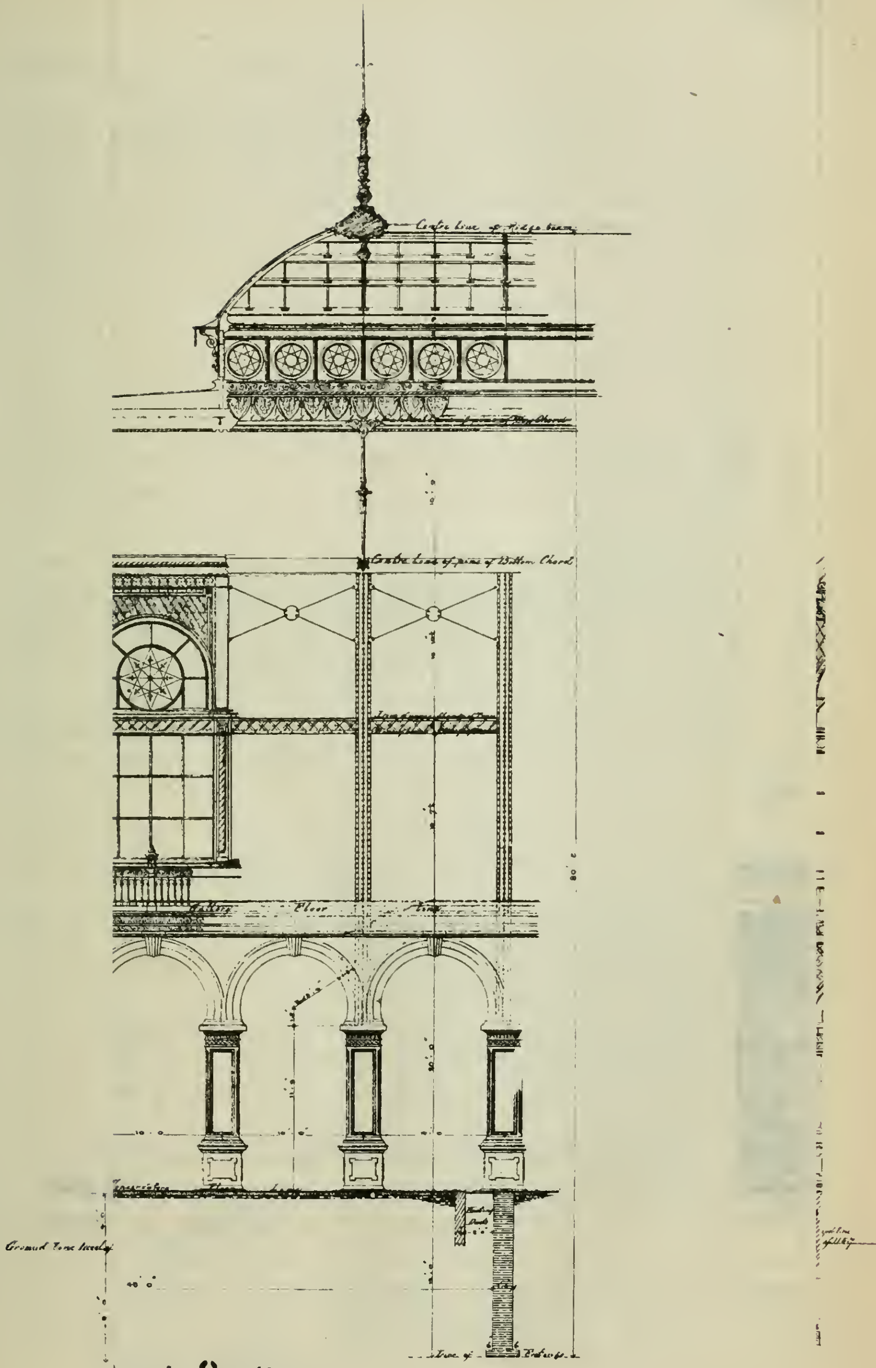
The grading is being done for the Agricultural Building, and the drainage put in, and the contractor, Mr. Quigley, will soon commence the erection of the superstructure.

The fire-proof floors of the Art Building are being laid, and some plastering done, and the work of completing the dome progressing very well.

On the Main Exhibition Building, the work of erecting the transept has commenced, and the roofing, glazing and flooring of the other portion is progressing favorably.

The work on the Machinery Building is being pushed forward as usual, the western half being nearly completed, the erection of the transept well under way, and the roof is being placed on the annex.

The walls of the boiler house for the water-works of the Exhibition, are ready for the roof, the stack nearly finished, and on the 26th of August, the stand-pipe was raised and placed in position, immediately north of the Art Building, and on line with the bridge across Lansdowne Valley.

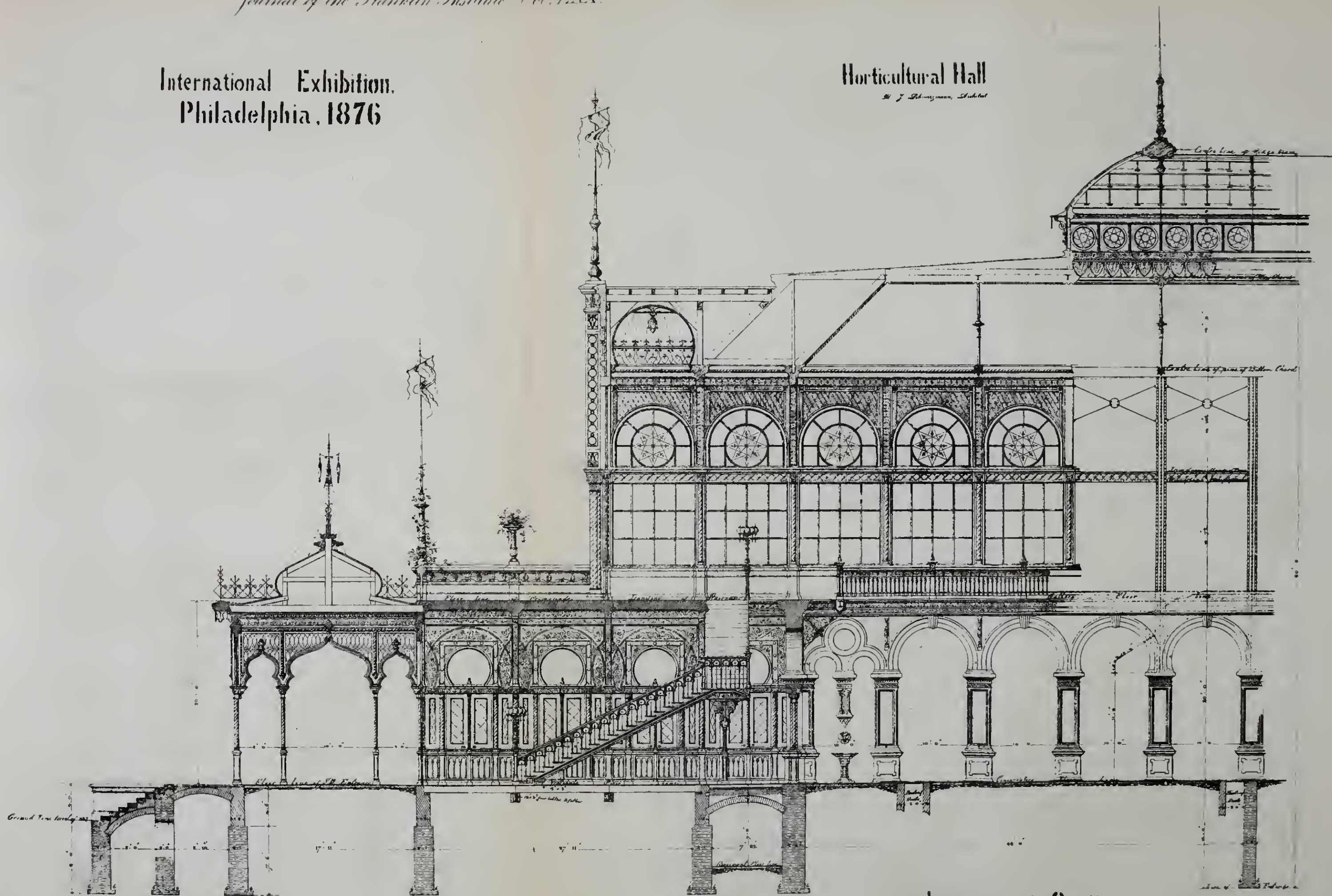


linal Section

International Exhibition.
Philadelphia, 1876

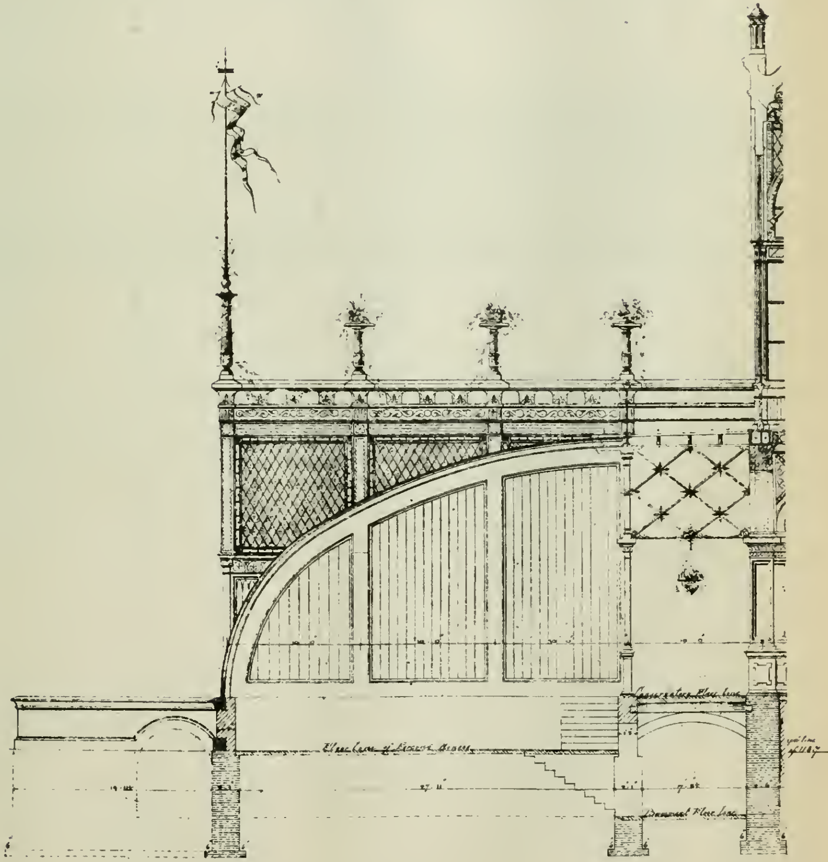
Horticultural Hall

H. J. Schwarzmann, Architect



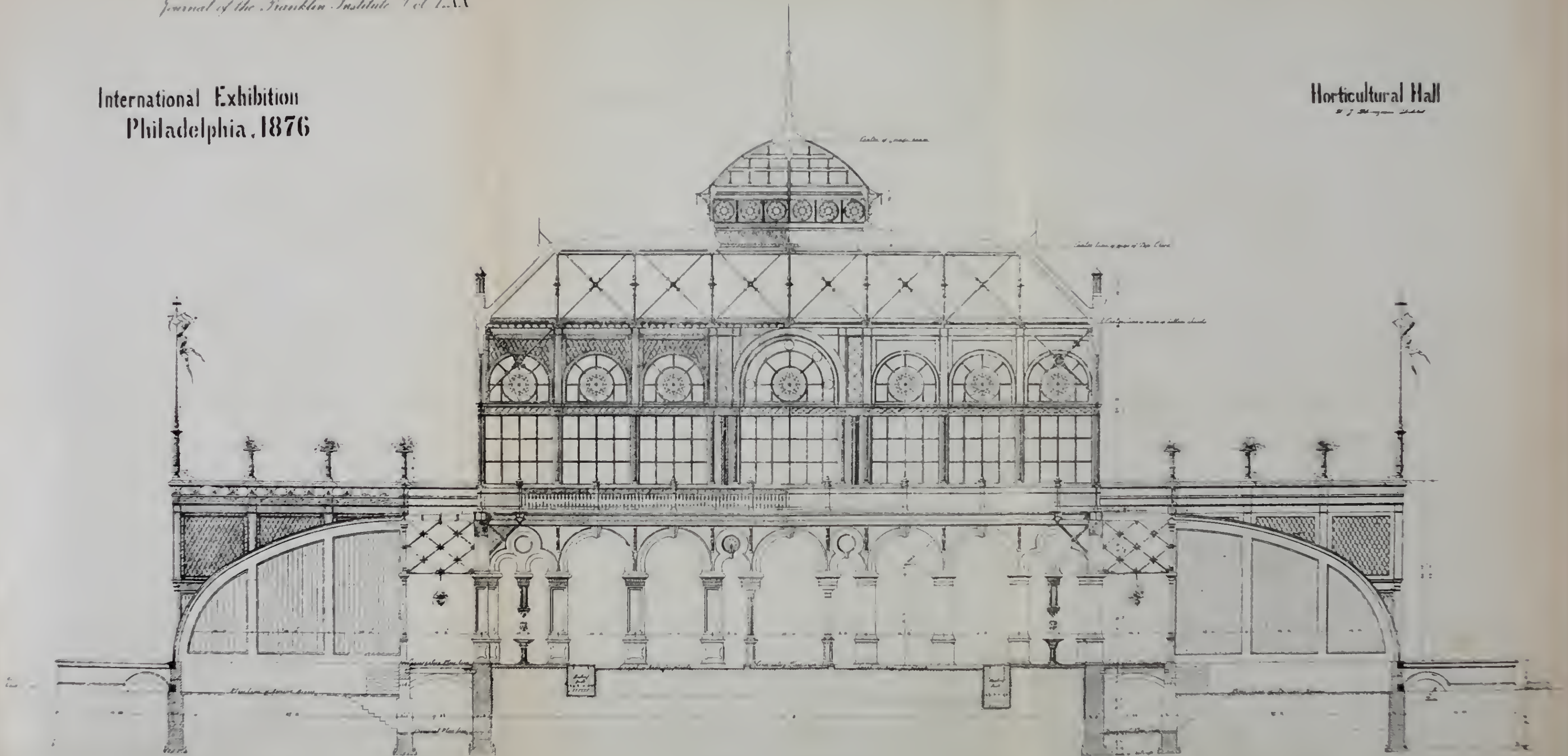
Longitudinal Section

International Exhibition
Philadelphia, 1876



International Exhibition
Philadelphia, 1876

Horticultural Hall



Transverse Section

The erection of the framing of the United States Government Building is commenced, and the foundations of that for the British Commission are laid. There seems no reason why the buildings should not be ready for the reception of goods at the time proposed.

K.

Manipulation of Blast Furnaces.—In the August number of the JOURNAL, a notice was inserted relative to the extraordinary feat of banking up a furnace for two hundred and seventeen days, and its successful recovery at the expiration of that time.

We have now to record the partial re-lining of a furnace without blowing out or accident. From a paper read before the American Institute of Mining Engineers, May, 1875, by Mr. Frank Firmstone, and published in the *Engineering and Mining Journal* of August 21st, is extracted the following:

At the distance of 5 or 6 feet below the tunnel head, on two opposite sides, the lining was completely gone for a height of about 4 feet, below which it increased gradually in thickness, being 9 inches thick about 3 feet lower down. Elsewhere at about the same level, the brick were not entirely gone, but were in some places only 2 or 3 inches thick, being still sufficient, however, to sustain the upper part, where the brick being above the level of the stock, were not at all worn.

The furnace was blown down, so that when we cast and closed the tuyeres, about 7 A.M., on December 8th, the top of the stock was about 24 feet below the filling-plates. The walls were quite hot, and a good deal of gas was given for several hours after the tuyeres were closed. The hopper and bell were thrown into the furnace, and were covered by filling several charges of cold stock over them, which at once greatly cooled off the top of the furnace. A wrought iron pipe, 30 inches in diameter, in five sections, each 6 feet long, was then put down, and made to stand upright, as nearly as possible in the centre of the furnace. Around this, we filled a double charge of coal, taking care to keep it up next the pipe, and let it get thinner as it got to the walls. This was covered with about 2 feet of fine ore, leaving the first joint in the pipe entirely uncovered. We were now ready to put in our scaffold to get at the brickwork. The scaffold was 10 feet in diameter, and was suspended from two stout poles (which reached across the top of the furnace, and rested on two trestles, about 6 feet high), by four chains and four pair of differential blocks,

whereby it could easily be raised and lowered as might be required. The frame of the scaffold, which had been well painted and sanded, was put together around the pipe in the centre of the furnace, and was floored over with 2 inch plank, leaving a hole 3 feet 4 inches square in the middle. Four pieces of 3x4 scantling, 16 inches long, were nailed upright at the four corners of this opening, and by nailing sheet iron from post to post, were formed into a square chimney surrounding the pipe. By this arrangement, most of the gas was drawn off through the central pipe, which got pretty hot soon after it was put in, and at the same time the strong ascending current, in the space between the square chimney and the pipe, carried off any gas which might leak through the fine ore, and brought a stream of fresh air down past the faces of the men as they worked at bricklaying.

These arrangements were completed about 7 P.M., when the night shift of bricklayers came on.

We at first tried to build up the holes, intending to wedge up the top brick, which were still perfect, on the new work, and then cut out and rebuild the thin places, a little at a time. We soon found that we could not get base enough for this, and determined to take out all the old work, from the top down, until we had from 6 inches to 9 inches to start on, and then rebuild, closing each course as we went.

Taking out these bricks was the hardest part of the job. They were, many of them, too hot to touch without hand-leathers, and the loam-filling between the front and back lining made a very thick dust.

After the top courses were out, we had to set props to prevent the lower bricks from falling in a mass. All the bricks were out about 4 A.M., on the 9th, and at 6.30 A.M., the day shift of bricklayers began to rebuild, finishing about 10 P.M.

Cast iron angle plates, 1 inch thick, were built in every joint, to cover the brick and prevent rapid wear in the future.

When the masonry was done, we lowered the scaffold to the bottom, knocked off the chimney, and took the bolts out of the lower joint in the pipe. After the chimney was removed, there was a slight smell of gas at the bottom, but the time spent in taking out the bolts was so short, that no one got sick from it.

The scaffold and the upper part of the pipe were then hoisted out, leaving the lower section in the furnace, and the rest of the night was spent in sending down the pipe, etc., and clearing away for put-

ting in the new bell and hopper. This was accomplished, and the blast put on by 3 P.M., of the 10th.

The furnace started without trouble, and although she slipped and worked irregularly for some weeks, she finally came to work very well, and the new part of the lining promises to last indefinitely.

On Meta-Brom-Toluol.—Dr. E. A. Grete.—As a matter of exceeding interest to some of our readers, we extract the following from the "*Chemical News*," July 30th, 1875, where it appears as the title of a paper in Justus Liebig's Annalen der Chemie, of June 25th, 1875. We can scarcely express our regret that the paper itself is not at our disposal for reproduction in its entirety.—This paper treats of the preparation of meta-brom-toluol; of meta-brom-sulphitoluol and its calcium, strontium, magnesium, copper, lead, and potassium compounds; and concludes that the sulphi-acid produced by the reaction of the meta-brom-toluol with fuming sulphuric acid, and corresponding to salicylic acid, belongs to the ortho series, and is consequently meta-brom-ortho-sulphi-toluol. The author further examines mono-nitro-meta-brom-toluol, mono-amido-meta-brom-toluol, meta-brom-amido-toluol sulphate, nitrate, hydrochlorate, and oxalate of meta-brom-toluydin; meta-brom-acettoluydin; dinitro-meta-brom-toluol; diamido-meta-brom-toluol, with its sulphate, hydrochlorate, nitrate and oxalate.

Toluole ($C_{14}\ H_8$) is one of a large number of hydro-carbons derived from coal oil, which have defined chemical composition. [Benzole ($C_{12}\ H_6$) is better known in popular language, and is the next combination above it in order of evaporation.] These hydro-carbons make regular combinations with bromine, chlorine, etc., which again become radicals and are acted upon in various ways and make further combination with other chemical substances, in endless permutation. Meta-brom-toluole is composed of bromine, carbon and hydrogen; and this remarkable collocation of words becomes intelligible to the professional chemist and informs him how completely the investigation has been made.

The Value of a Dozen.—As the derivation from the French douzaine implies, it is generally presumed that a dozen implies twelve things, but in the Staffordshire potteries, and in the earthenware trade (queensware in Philadelphia, crockery in other places) a dozen to this day represents that number of any special article which can be offered at a fixed price. That is, the price is fixed and the number to the

dozen varies. For instance, the pitchers (which are called "jugs" in the trade) are sold as 2, 3, 4, 6, 9, 12, 18, 24, 30, 36 pieces to each dozen, the price for a dozen being constant. The ordinary pitcher, holding a quart, is *a twelve* or twelve to the dozen, while a pint pitcher is twenty-four to the dozen, and is so-called when dealing in that size. Few of the articles of the trade are sold in dozens of twelve, plates being almost the only ones, and some of them are sold at sixty to the dozen. Beside these curiosities in figures, the potters have peculiar names, muffins, twiflers, etc., that make up a trade language of itself. The quantities for dozens are, we think, *yet* preserved in the whole-sale, or package trade.

The Annual Consumption of Iron per Inhabitant in the United States.—We are favored by an article compiled by Mr. J. M. Swank, Secretary American Iron and Steel Association, from which it appears that in 1870, the consumption per capita was 171 pounds.

This result was reached from the returns of the United States census. Mr. Swank has endeavored to deduce from the data in his possession, the consumption in the United States in 1872, and he estimates the quantity for that year to be 223 pounds per inhabitant. Mr. Swank further deduces from English statistics, that the quantity of iron per inhabitant of the United Kingdom, was 220 pounds for the same year, 1872.

Contrasting the above quantities with those given in the report of the Hon. Abram S. Hewitt, U. S. Commissioner to the Paris Exposition, of 1867, namely: 189 pounds in England; 100 pounds in America; 69½ pounds in France, we have a basis of estimate of the magnitude and growth of the manufacture of iron.

The estimates are as follows, in tons of 2000 pounds:

Gross production of Iron and Steel in the U. S. in 1872,	4,829.303
Deduct Exported Iron and Steel,	306,680
Total consumption,	4,522,623
To 40,000,000 of inhabitants.	
Gross production of Iron and Steel (in tons of 2240 pounds) in the United Kingdom, in 1872,	6.741,929
Deduct Exportation, Manufactured or otherwise,	3,603.537
Total consumption,	3,138,392
To 31,800,000 of inhabitants.	

Civil and Mechanical Engineering.

ON THE STRENGTH OF PULLEY-ARMS.

The correct method of proportioning the arms of pulleys, wheels, etc., when the arms, rim, and hub are all cast in one piece, or when they are all so firmly fastened together as to be equivalent to being made in one piece, is from the following facts evidently not understood by writers on mechanics. Rankine, in his "Mills and Millwork," page 555, gives formulæ for calculating the dimensions of pulley-arms, and remarks in regard to the above case, that "the greatest bending moment is exerted on each arm at two points, close to the rim and close to the boss respectively," and shows, by his formula, that the arms should have the same strength at each of these points. Other eminent writers declare that the case is the same as the one, common in machinery, of a beam built in at one end, and loaded at the other *free end*, and the shape usually given to pulley-arms seems to show that this is the common belief, since they are almost invariably made strongest near the hub or boss, and weakest near the rim.

On account of this contradiction of authorities, and believing that neither of the above was the true theory, the writer was led to solve the problem for himself, and the main steps of the solution with its result are here reproduced.

First in order to discuss the stresses acting on the different parts of a loaded beam, we must determine the shape assumed by the *elastic curve*, being the axis of the beam when slightly bent by the forces acting on it. We will therefore start with the general formula for the elastic curve of prismatic beams, acted upon by vertical forces.

(1) $$WE\frac{d^2y}{dx^2} = M.^*$$

in which W is the amount of inertia of the section of the beam, E the coefficient of elasticity, and M the resultant moment of all forces

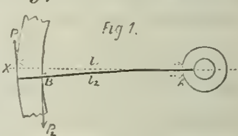
* See Weisbach's Mechanics, Part I, ¶ 223.

acting on the section at that point of the elastic curve whose co-ordinates are x and y. The axis of X coincides with the axis of the beam when not loaded, the beam being straight in that condition, and the origin of co-ordinates is at the point of support. Suppose the beam discussed to be built in at one end, and acted upon by two forces, P_1 and P_2, at distances l_1 and l_2 from the point of support; then M would be equal to $P_1(l_1 - x) + P_2(l_2 - x)$, and after substituting this value, the two integrations of formula (1) give the following formulæ:

$$(2) \qquad \frac{dy}{dx} = \tan \alpha = \frac{P_1(2l_1x - x^2) + P_2(2_2lx - x^2)}{2WE}$$

$$(3) \qquad y = \frac{P_1(3l_1x^2 - x^3) + P_2(3l_2x^2 - x^3)}{6WE}$$

in which α is the angle of the curve at the point xy, with the axis of X. These formulæ apply to all cases which fulfill the above conditions, and it will be seen from Fig. 1 that pulley-arms fulfill those conditions, for the reason that they may be considered as built in at the hub or boss, A, and acted upon at the rim by the forces P_1 and P_2. P_1 acts in an opposite direction to P_2, and is just sufficient to maintain the arm in a radial direction at the point B, or where the arm meets the rim. Call the co-ordinates of this point l_2 and y_2, and the angle α_2, and we have the following relation:



$$(4) \qquad \tan \alpha_2 = \frac{y_2}{l_2 + r}$$

r being the radius of the hub. Referring equations (2) and (3) to the point B, by substituting l_2 for x and then substituting the values of $\tan \alpha_2$ and y_2, thus found in equation (4) and reducing, we have

$$(5) \qquad P_1 = - P_2 \frac{l_2(l_2 + 3r)}{3l_1l_2 - 2l_2^2 + 6l_1r - 3l_2r}$$

Substituting this value of P_1 in the above value of the moment M, and then putting $M = 0$, and solving for x, in order to find what point of the arm is acted upon by no bending moment, we find

$$(6) \qquad x_0 = \frac{l_2(2l_2 + 3r)}{3(l_2 + 2r)}$$

Suppose r to be any multiple of l_2, as ml_2, then if we substitute this

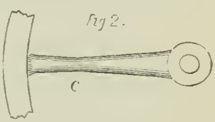
value of r in equation (6), we find

$$x_0 = \frac{3m+2}{3(2m+1)} l_2 \tag{7}$$

and if we put

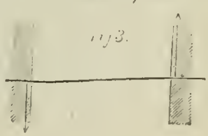
$m = \infty$,	we find	. . .	$x_0 = \frac{1}{2} l_2$.
$m = 1$,	"	. . .	$x_0 = \frac{5}{9} l_2$.
$m = 1\text{-}2$,	"	. . .	$x_0 = \frac{7}{12} l_2$.
$m = 1\text{-}4$,	"	. . .	$x_0 = \frac{11}{18} l_2$.
$m = 1\text{-}10$,	"	. . .	$x_0 = \frac{23}{36} l_2$.
$m = 0$,	"	. . .	$x_0 = \frac{2}{3} l_2$.

We see from this that as m, and therefore r, decreases, x_0 rapidly approaches the value 2-3 l_2, and in the ordinary cases in practice m is so small that it may be neglected without appreciable error. We find therefore that the point of the arm which is acted upon by no bending force is two-thirds the length of the arm from the hub. Fig. 2 represents an arm constructed on this principle. The force transmitted by the pulley tends to shear the arm at the point C, while one-third of the force tends to break the arm at the rim, and two-thirds to break it at the hub. The arm should therefore be twice as strong at the hub as at the rim. It should be, moreover, stronger at the hub than Rankine's formula requires, in the ratio of $\frac{2}{3}$ to $\frac{1}{2}$, but may be weaker than the ordinary method requires in the ratio of $\frac{2}{3}$ to 1.



This result also shows the best place to connect the arms when the hub and rim are made separately, for if two-thirds of the arm is cast with the hub, and one-third with the rim, the joint need not be made stiff, for even if it is a hinge joint, the arm will not be weakened.

We have found, in the table under equation (7), that if $m = \infty$, the point x_0 comes in the middle of the arm, and the bending moment at the rim and hub would therefore be the same in this case, and the arm would receive the same proportions from our formulæ as from Rankine's. But in putting $m = \infty$, we assume that the hub is infinitely large compared with the length of the arm, which is equivalent to supposing it a beam fixed between two parallel walls, which tend to slide past each other, as in Fig. 3. Rankine has therefore supposed that pulley-arms are acted upon in the same way as the beam of Fig. 3, the error of which is discovered above.



Another interesting fact shown by the table under formula (7) is, that while the radius of the hub as compared with the arm diminishes from infinity to zero, the point of no moment moves from the middle of the arm to a point at a distance from the rim, of one-third the length of the arm, and is in no case outside of these two points.

A. K. MANSFIELD, M.E.

Cordova, Argentine Republic, S. A., July 5, 1875.

[This discussion of the strength of pulley-arms is a very valuable addition to the application of mathematical study in mechanical construction. It must not be overlooked, however, in the consideration of the strength of the arm of any fly-wheel or pulley, that not only the strains resulting from work or changes of speed will enter, but also any strains existing in the metal of the arm itself must be allowed for. It is necessary that the thickness of metal in the arm should bear such relation to the masses or thickness of the hub or rim, as will allow nearly uniform cooling of all the parts. The founder can, by judicious uncovering of disproportioned rims, hubs, or arms, measurably overcome the irregularities of cooling and consequent shrinkage; but a pulley, or more especially a fly-wheel with arms abundantly strong by calculation for all possible working service, can, with difficulty, be got out of the sand without hot or cold cracks in arms or hub. And if an apparently sound casting is had, there will exist in the arms strains of shrinkage which will seriously impair its strength.

These strains are frequently so great that pulleys may, and do fail or break upon, and sometimes after service, and even, at times, fly unexpectedly in the workshop. The greatest variation of conditions are these two cases: one of a fly-wheel where the weight is required in the rim, and the other of a pulley where any thickness of rim which can be cast is superabundant to carry the adhesion of a belt. It may be said roughly that in the case of the fly-wheel, an oval arm whose thickness shall not be less than one-third that of the least dimension of the rim, and whose sectional area at the point of junction shall not be less than one-fourth that of the rim; and in the case of the pulley, an arm whose thickness shall not be greater than twice that of the rim, and whose sectional area shall not be greater than one-third the rim, will suffice. That with these proportions of arms, and with hubs to correspond, the care of the founder can insure castings *measurably* free from strains. A full discussion and scale resulting from it, of the proportions of arms of pulleys with straight arms and solid hubs, embracing all the conditions of light pulley and heavy balance or gear wheel, from the founder's point of view, would supplement this note of Mr. Mansfield very satisfactorily.]—ED. JOUR.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. ISHERWOOD, U. S. N.

[Continued from Vol. lxx, page 116.]

Experiments made to ascertain the dynamometrical resistances to dragging, of the experimental screws A, B, C, D, E, F, and H, of the United States steam-launch No. 4, when it was towed by the United States screw-steamer Monterey, with its screws disconnected from its engines, and revolving freely by the pressure of the water on the forward side of their blades, and held stationary in different positions.

The following experiments are the only ones of their kind of which the writer has knowledge. They supply, in part, a great desideratum in marine steam-engineering, and show the loss of speed sustained by a steamship when under sail alone, consequent on the dragging of its screw through the water in different stationary positions, and when revolving freely by the pressure of the water on the forward surface of their blades. They also show the comparative resistance of screws of different kinds, with different proportions and number of blades, under the above conditions.

The screws employed in these experiments were screws A, B, C, D, E, F, and H, of the United States steam-launch No. 4, embracing all, with exception of screw G, that were used in the experiments made with that launch and detailed in the immediately preceding report.

During the experiments about to be described, the launch was at a less draught of water than during those referred to, and had the following dimensions and proportions in the water:

Length, in feet, on load water-line, from forward edge of rabbet of stem to after side of stern-post, .		54·40
Extreme breadth, in feet, on load water-line, .		11·88
Depth, in feet, of hull from load water-line to lower edge of rabbet of keel, ...	forward	2·160
	mean	2·891
	aft	3 622

Table No. 9, containing the data and results of an experiment made with the machinery of the United States steam-launch No. 4, with screw G, to ascertain the evaporative efficiency of the boiler with anthracite, and the cost of the indicated and dynamometrical horse-power in pounds' weight of steam and of fuel consumed per hour. (During this experiment, the vessel was secured to the wharf of the Mare Island navy-yard, California, with the stern raised six inches and held suspended by a floating crane.)

Date of commencing the experiment..........9.23 A. M., March 30th, 1870.	
VESSEL.	
Vessel's draught of water, in feet and inches ... forward	3 7
Vessel's draught of water, in feet and inches ... mean	3 11½
Vessel's draught of water, in feet and inches ... aft	4 4
TOTAL QUANTITIES.	
Duration of the experiment, in consecutive hours and minutes	9·18
Number of double strokes of engines' pistons, and of revolutions of the screw	65,844·
Number of pounds of anthracite consumed	1,910·
Number of pounds of refuse from the anthracite in ash, clinker, etc	310·
Number of pounds of combustible consumed	1,600·
Per centum of the anthracite in refuse of ash, clinker, etc	16·23
Cubic feet of feed-water pumped into the boiler from the tank	220·212
Pounds of feed-water pumped into the boiler from the tank	13,728·439
RATE OF COMBUSTION.	
Pounds of anthracite consumed per hour	205·376
Pounds of combustible consumed per hour	172·043
Pounds of anthracite consumed per hour, per square foot of grate surface.	24·655
Pounds of combustible consumed per hour, per square foot of grate surface.	20·653
Pounds of combustible consumed per hour, per square foot of heating surface	0·927
TEMPERATURES.	
Temperature, in degrees Fahrenheit, of the external atmosphere	61·
Temperature, in degrees Fahrenheit, of the engine and boiler room	88·
Temperature, in degrees Fahrenheit, of the bay water	60·
Temperature, in degrees Fahrenheit, of the feed-water in the tank	58·
Temperature, in degrees Fahrenheit, of the feed-water entering the boiler.	125·
ENGINES.	
Number of double strokes made per minute by the engines' pistons	118·
Steam-pressure in boilers in pounds per square inch above the atmosphere.	92·
Position of the throttle-valve	wide open.
Fraction of the stroke of the piston completed when the steam was cut off.	0·858
Thrust of the screw in pounds, per dynamometer	858.55
Height of the barometer in inches of mercury	29·38
STEAM PRESSURES IN CYLINDERS, PER INDICATOR.	
In pounds per square inch above zero at commencement of stroke of pistons	104·2
In pounds per square inch above zero at point of cutting off the steam	98·7
In pounds per square inch above zero at end of stroke of pistons	81·2
In pounds per square inch above zero against the pistons during their stroke	21·1
Mean gross effective pressure on pistons, in pounds per square inch	80·9
Mean total pressure on pistons, in pounds per square inch	102·0
Mean net pressure on pistons, in pounds per square inch	78·9

POWER.	
Absolute:	
Gross effective indicated horse-powers developed by the engines.......	27·221
Total horse-powers developed by the engines..........................	34·320
Net horse-powers developed by the engines............................	26·548
Dynamometrical horse-powers developed by the engines...............	23·025
Economic:	
Pounds of anthracite consumed per hour, per gross effective indicated horse-power..........	7·545
Pounds of anthracite consumed per hour, per total horse-power.......	5·984
Pounds of anthracite consumed per hour, per net horse-power.........	7·736
Pounds of anthracite consumed per hour, per dynamometrical horse-power..........	8·920
Pounds of combustible consumed per hour, per gross effective indicated horse power..........	6·320
Pounds of combustible consumed per hour, per total horse-power.....	5·014
Pounds of combustible consumed per hour, per net horse-power.......	6·480
Pounds of combustible consumed per hour, per dynamometrical horse-power..........	7·472
Pounds of feed-water consumed per hour, per gross effective horse-power..........	54·229
Pounds of feed-water consumed per hour, per total horse-power.......	43·012
Pounds of feed-water consumed per hour, per net horse-power.........	55·604
Pounds of feed-water consumed per hour, per dynamometrical horse-power..........	64·112
VAPORIZATION.	
Total:	
Total number of pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the atmospheric pressure of 29·92 inches of mercury..........	13,876·906
Total number of pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 212 degrees Fahrenheit, and vaporized under the atmospheric pressure of 29·92 inches of mercury..........	15,499·255
Economic:	
Pounds of water vaporized from 100° Fahrenheit by one pound of anthracite..........	7·265
Pounds of water vaporized from 100° Fahrenheit by one pound of combustible..........	8·673
Pounds of water vaporized from 212° Fahrenheit by one pound of anthracite..........	8·115
Pounds of water vaporized from 212° Fahrenheit by one pound of combustible..........	9·687
CONDENSATION.	
Pounds of steam discharged from the cylinders into the atmosphere, calculated from the pressure of the steam at the end of the stroke of the pistons..........	8,452·090
Pounds of steam condensed in the boiler and cylinders to furnish the heat transmuted into the total power developed by the engines, according to Joule's equivalent..........	930·696
Sum of the above two quantities..........	9,382·786
Per centum of the steam evaporated in the boiler, condensed in the boiler and cylinders to furnish the heat transmuted into the total power developed by the engines..........	6·78
Per centum of the steam evaporated in the boiler not accounted for by the indicator..........	31·65
Difference, due to all causes, between the weight of feed-water pumped into the boiler, according to the tank, and the weight of steam discharged from the cylinders into the atmosphere at the end of the stroke of the pistons, per indicator, expressed in per centum of the feed-water........	38·43

Load-draught, in feet, of water from the bottom of the keel, ...	forward	2·66
	mean	3·62
	aft	4·58
Area, in square feet, of the greatest immersed transverse section, ...		21·83
Area, in square feet, of the immersed external surface of the hull proper, exclusive of keel and rudder, ...		571·
Area, in square feet, of the immersed external surface of the hull, inclusive of keel (100·8 square feet) and rudder (13·2 square feet,)		685·
Displacement, (cubic feet), ...		693·117
Displacement, (tons), ...		19·842
Ratio of the area of the greatest immersed transverse section to the area of its circumscribing parallelogram, ...		0·6356
Ratio of the displacement to its circumscribing parallelopipedon, ...		0·3710

The remaining dimensions of the launch can be obtained from the immediately preceding report. Its hull, during the experiments about to be described, had 0·265 foot draught of water less than during the experiments on the propelling efficiency of the screws, with, of course, a corresponding decrease in the area of the greatest immersed transverse section, in the area of the immersed external surface, and in the displacement. The greatest immersed transverse section and the immersed solid of the hull were also sharper than with the greater draught of water. The resistance of the hull must, therefore, have been less. It was in fact $\left(\frac{707 - 631 \times 100}{707} = \right) 10\tfrac{3}{4}$ per centum less at the speed of seven geographical miles per hour, as measured by the dynamometer.

MANNER OF MAKING THE EXPERIMENTS.

The screw-steamer Monterey, by which the steam-launch No. 4 was towed, is a small tug attached to the Mare-Island navy-yard. On the deck of this vessel, at the stern, the bed-plate of a very sensitive dynamometer was bolted, consisting of a single horizontal lever, one end of which bore against a vertical steel knife-edge, by means of a steel bush, the knife-edge being firmly secured to the bed-plate.

The other end was articulated to a spiral spring, the opposite extremity of which, in its turn, was also articulated to the bed-plate. At one-tenth of the distance between the points at which the lever was secured to the bed-plate, measured from the end opposite that to which the spring was attached, was a vertical steel knife-edge bearing against a steel bush. To the extremities of this knife-edge a small steel loop U-shaped, was articulated, and to this loop the tow-line from the steam-launch was fastened. The leverage of the spring against the tow-line was exactly ten to one. The weight of the lever was supported on delicate brass friction-rollers, polished, and moving on polished brass ways. Great precaution was thus used to make the friction of the dynamometer as little as possible, and it was reduced to the extent that one-fourth of a pound tension on the spring was sufficient to give movement to the unloaded instrument.

A scale, graduated to pounds by careful trial for its whole length, was attached to the base-plate of the spring, and the opposite end of the spring carried a pencil, which traced on a moving sheet of paper the curve of tensions described by the combined movement of the pencil and paper, and measured by the scale. The paper was wound around a light polished brass cylinder of eight inches diameter, the steel axle of which, at each end, was supported in brass bearings secured to the bed-plate of the dynamometer. This cylinder received a rotary movement from the screw-shaft of the vessel by means of two shafts at right angles to each other, the first being horizontal and lying just above the deck, the second being vertical and connecting the first, by my means of mitre-gearing, with the screw-shaft. The vertical shaft received its movement from the screw-shaft by means of an endless worm and wheel, and the cylinder received its movement from the horizontal shaft by similar mechanism. The dynamometer-diagram, thus traced, was sufficiently long for a single run of the vessel, so that it was continuous from one end of the base to the other.

The base used was the one employed in the previous experiments on the propelling efficiencies of the screws of steam-launch No. 4 already referred to. It was a straight line 8,950 feet long, in smooth water, and under the lee of the high ground of Mare Island.

The tow-line was a small cord, just strong enough to sustain the maximum tension without breaking, and 170 feet in length between the vessels. It was attached, by means of a bridle, to the bows of

the launch about 18 inches above the deck, so that the towing strain was exactly in the vertical plane of the keel. The screw of the Monterey had but a very small slip when towing the launch, so that any water thus thrown backward lost its movement within a very short distance and exercised no effect upon the following launch. The strain on the dynamometer exerted by the tow-line alone, at different angles of inclination from the vertical, was experimentally ascertained and deducted from the strain on the dynamometer when towing the launch with the same angle of inclination of the tow-line.

Throughout these experiments both vessels remained at exactly the same draught of water, and during each trial the steam-pressure in the Monterey's boiler, the position of the throttle-valve of its engine, and all other conditions, were maintained as nearly constant as possible.

The speed of the launch was ascertained both by the shore-marks and by the Berthon tube, in the same manner as described by the preceding experiments on the propelling efficiency of the screws. The number of revolutions made by the screw, when revolving freely by the pressure of the water on the forward surface of their blades, was ascertained by a counter, in the manner described for the experiments already referred to. The same persons were employed in both sets of experiments, and were perfectly expert in making them. Nothing that could conduce to extreme accuracy was omitted. During these trials, the screw-shaft was disconnected from the crank-shaft of the launch's engines, so that in revolving it had only the friction of its journals and collars to overcome. Its stuffing-box, at the inboard end of the dead-wood, was packed barely sufficiently tight to prevent water-leakage.

The mean tension on the tow-line was obtained by dividing the straight base of each dynamometer-diagram into abscissæ of half an inch length, and erecting therefrom ordinates at right angles to the base, and cutting the curve of tensions. The mean length of these ordinates, measured by the scale of the spring, and multiplied by the leverage of the latter, gives the mean tension on the tow-line. The base-line of the diagram is described by revolving the cylinder without tension on the spring.

Each trial consisted of six runs over the base, three in each direction, and were made with the screws in the following positions, namely:

First. With screw A, 11 inches long in the direction of the axis, two-bladed, and of 5·136 feet pitch, six runs were made with the blades in a vertical position immediately behind the stern-post of the vessel, the latter having the speed of seven geographical miles per hour, as nearly as could be obtained. Then six runs were made with the blades at right angles to their former position—that is horizontally or square across the vessel—at as nearly the speed of seven geographical miles per hour as could be obtained. Finally, the screw being allowed to freely revolve, six runs were made at the speed of seven geographical miles per hour, as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$, geographical miles per hour, as nearly as could be obtained.

Second. With screw B, which was exactly the same as screw A, except that its length was $8\frac{5}{8}$ inches in the direction of the axis instead of 11 inches, precisely the same set of trials was made as with screw A.

Third. With screw C, which was exactly the same as screw A, except that its length was $5\frac{1}{2}$ inches in the direction of the axis, precisely the same set of trials was made as with screw A.

Fourth. With screw D, which was exactly the same as screw A, except that its length was $3\frac{1}{8}$ inches in the direction of the axis, precisely the same set of trials was made as with screw A.

Fifth. With screw E, which was composed of four blades equispaced around the axis, the length of each blade in the direction of the axis being $5\frac{1}{2}$ inches, and the pitch, surface, and diameter the same as those of screw A, six runs were made with two blades in the vertical position immediately behind the stern-post of the vessel, and the other two blades in the horizontal position or square across the vessel, the vessel's speed being 7 geographical miles per hour, as nearly as could be obtained. Then six runs were made with the blades of the screw standing at the angle, of 45 degrees with the horizon, the speed of the vessel being 7 geographical miles per hour, as nearly as could be obtained. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour, as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$ geographical miles per hour, as nearly as could be obtained.

Sixth. With screw F, which was 11 inches long in the direction of its axis, and composed of four blades arranged in two pairs—the

blades of each pair being directly opposite each other—and one pair placed immediately behind the other, so that when viewed in projection on a plane at right angles to the axis, the screw appeared to be two-bladed, six runs were made with the blades in a vertical position immediately behind the stern-post of the vessel, the latter having the speed of 7 geographical miles per hour as nearly as could be obtained. Then six runs were made with the blades at right angles to their former position—that is, horizontally or square across the vessel—at as nearly the speed of 7 geographical miles as could be obtained. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$ geographical miles per hour, as nearly as could be obtained. Screw F is also known as the Mangin or duplex screw; and its pitch, surface, and diameter, were the same as those of screw A.

Seventh. With screw H, which was a three-bladed Griffith screw of 11 inches extreme length, and a pitch that expanded from $6\frac{2}{3}$ feet to $7\frac{1}{3}$ feet, the diameter being the same as that of screw A, six runs were made with one blade vertical *below* the shaft—that is, immediately behind the stern-post of the vessel—and the remaining two blades *above* the shaft at angles of 60 degrees from the vertical, the vessel's speed being 7 geographical miles per hour as nearly as could be obtained. Then six runs were made with one blade vertical *above* the shaft—that is immediately behind the stern-post of the vessel—and the remaining two blades *below* the shaft at angles of 60 degrees from the vertical, the vessel's speed being 7 geographical miles per hour as nearly as could be obtained. Then, six runs were made with one blade horizontal—that is, square across the vessel on one side of the stern-post—and the remaining two blades on the other side of the stern-post at angles of 60 degrees from the vertical. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$ geographical miles per hour, as nearly as could be obtained.

RESULTS.

Of the resistance of the hull, per se, that is, its resistance without any screw attached.—Steam-launch No. 4 was towed at all speeds from $5\frac{1}{2}$ to $7\frac{1}{2}$ geographical miles per hour, as nearly as could be

obtained, increasing by one-fourth of a geographical mile per hour. Six runs were made at each speed, and the mean taken of the experimental speeds and of the corresponding dynamometer-diagrams. A comparison of these means with each other showed that, within the above limits, the resistance of the hull was in the ratio of the square of its speed; the extreme variation from this law on either side of the mean being only 2 per centum of the mean, and was as often greatest for the low speeds as for the high. *At the speed of* 7 *geographical miles per hour the resistance of the hull, as given by the mean of all the dynamometer-diagrams taken at all the different speeds, and reduced in the above proportion, is* 631 *pounds.*

When the steam-launch, instead of being towed, was propelled by its own screws, the resistance of its hull at the speed of 7 geographical miles per hour was 707 pounds; the difference in the two cases is consequently (707—631=) 76 pounds, or $\left(\frac{76 \times 100}{707} =\right) 10\frac{3}{4}$ per centum of the larger quantity. A part of this is due to the vessel's less draught of water when it was towed than when it was propelled by its own screws. In the former case its greatest immersed transverse section was 21·83 square feet; in the latter case 24·98 square feet; difference, $\left(\frac{24{\cdot}98 - 21{\cdot}83 \times 100}{24{\cdot}98} =\right) 12{\cdot}61$ per centum of the larger quantity. In the latter case the area of the immersed external surface of the hull was 717 square feet; in the former case 685 square feet; difference, $\left(\frac{717 - 685 \times 100}{717} =\right) 4{\cdot}46$ per centum of the larger quantity. In the latter case the displacement was 23·3053 tons; in the former case, 19·8420 tons; difference, $\left(\frac{23{\cdot}3053 - 19{\cdot}8420 \times 100}{23{\cdot}3053} =\right) 14{\cdot}86$ per centum of the larger quantity. The mean of the three $\left(\frac{12{\cdot}61 + 4{\cdot}46 + 14{\cdot}86}{3} =\right) 10{\cdot}64$ per centum, is almost the exact experimental difference of the resistance in the two cases.

Results with screw D.—This screw was two-bladed, and had the least surface of any employed in these trials; it is therefore convenient to first ascertain its results. The principal portion of its pro-

jected area on a plane at right angles to the axis is nearly masked or covered by the stern-post of the vessel when the two blades are placed vertically behind it.

When the blades of screw D held stationary in the vertical position immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 657 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remained for the resistance of the screw, *per se*, 26 pounds. Consequently, the screw, with its blades in the vertical position, increased the vessel's resistance $\left(\frac{26 \times 100}{631} =\right) 4{\cdot}12$ per centum, and decreased its speed $(\sqrt{631} : \sqrt{657} :: 7 : 7{\cdot}1428$; and $7{\cdot}1428 - 7{\cdot} =) \; 0{\cdot}1428$ geographical miles per hour, or $\left(\frac{0{\cdot}1428 \times 100}{7{\cdot}1428} =\right) 2$ per centum.

With the blades of screw D held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw, at the speed of 7 geographical miles per hour, was 756 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remains for the resistance of the screw, *per se*, 125 pounds. Consequently, the screw, with its blades in the horizontal position, increased the vessel's resistance $\left(\frac{125 \times 100}{631} =\right)$ 19·81 per centum, and decreased its speed $(\sqrt{631} : \sqrt{756} :: 7 : 7.6620$ and $7{\cdot}6620 - 7. =) \; 0{\cdot}6620$ geographical mile per hour, or $\left(\frac{0{\cdot}6620 \times 100}{7{\cdot}6620} =\right)$ 8·64 per centum.

From the above it appears that screw D, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{125}{26} =\right) 4{\cdot}808$ times the resistance it had when its blades where held in the vertical position, immediately behind the vessel's stern-post.

When screw D was allowed to revolve freely by the pressure of the water of the forward face of its blades, it made 757 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was conse-

quently $\left(\frac{6086 - 5{\cdot}136 \times 757 \times 100}{6086} = \right)$ 36·12 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 2·528 geographical miles per hour. The revolutions of this screw were not uniform, the rotary speed fell off greatly as the blades came into the vertical position behind the stern-post of the vessel, at which point there was a decided hesitation in passing, after which the rotary speed increased. That speed appeared uniform for a considerable portion of the half revolution, the falling off occurring as the blades became masked by the stern-post, owing to their excessive narrowness in projecting on a plane at right angles to their axis.

With the vessel at the speed of seven geographical miles per hour and screw D revolving freely, the aggregate resistance of vessel and screw was 685 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 54 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{54 \times 100}{631} = \right)$ 8·56 per centum; and decreased its speed ($\sqrt{631} : \sqrt{685} :: 7 : 7{\cdot}2934$; and $7{\cdot}2934 - 7{\cdot} =$) 0·2934 geographical mile per hour, or $\left(\frac{0{\cdot}2934 \times 100}{7{\cdot}2934} = \right)$ 4·02 per centum.

When a two-bladed screw has so small a fraction of the pitch as screw D, namely, 0·1014, whereby its blades are nearly masked by the vessel's stern-post, it appears that the resistance due to the screw when revolving freely is 2 per centum of the resistance of the vessel, *per se*, more than when it is held stationary with its blades behind the stern-post in the vertical position; but 3 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel. The resistance of the revolving screw in this case is greater, proportionally, than when a larger fraction of the screw is used, owing to its making a less number of revolutions per mile in consequence of the falling off of its rotary speed as its blades pass the stern-post.

Results with screw C.—This screw was two bladed, and had the next greatest surface to screw D. Their surfaces compared as $3\frac{1}{8}$ to $5\frac{1}{2}$ and were of exactly the same kind. A considerable portion of the

surface of screw C projected on each side of the vessel's stern-post when the blades were in the vertical position.

With the blades of screw C held stationary in the vertical position immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 721 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 90 pounds. Consequently, the screw, with its blades in the vertical position increased the vessel's resistance $\left(\frac{90 \times 100}{631} =\right)$ 14·26 per centum; and decreased the speed ($\sqrt{631} : \sqrt{721} :: 7 : 7{\cdot}4826$; and $7{\cdot}4826 - 7 =$) 0·4826 geographical mile per hour, or $\left(\frac{0{\cdot}4826 \times 100}{7{\cdot}4826} =\right)$ 6·45 per centum.

With the blades of screw C held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 851 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remains for the resistance of the screw, *per se*, 220 pounds. Consequently, the screw with it blades in the horizontal position, iucreased the vessel's resistance $\left(\frac{220 \times 100}{631} =\right)$ 34·86 per centum; and decreased its speed ($\sqrt{631} : \sqrt{851} :: 7 : 8{\cdot}1292$ and $8{\cdot}1292 - 7 =$) 1·1292 geographical miles per hour, or $\left(\frac{1292 \times 100}{8{\cdot}1292} =\right)$ 13·89 per centum.

From the above, it appears that screw C, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{220}{90} =\right)$ 2·444 times the resistance it had when its blades were held in the vertical position, immediately behind the vessel's stern-post.

When screw C was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from 5½ to 7 geographical miles per hour. The axial speed of the screw was consequently

$\left(\frac{6086 - 5{\cdot}136 \times 921 \times 100}{6086} = \right) 22{\cdot}28$ per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

With the vessel at the speed of 7 geographical miles per hour, and screw C revolving freely, the aggregate resistance of vessel and screw was 698 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the screw, *per se*, 67 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{67 \times 100}{631} = \right) 10{\cdot}62$ per centum; and decreased its speed ($\sqrt{631} : \sqrt{698} :: 7 : 7{\cdot}3623$; and $7{\cdot}3623 - 7. =$) 0·3623 geographical mile per hour, or $\left(\frac{0{\cdot}3623 \times 100}{7{\cdot}3623} = \right) 4{\cdot}92$ per centum.

From the foregoing it appears that the resistance due to screw C, when revolving freely, is 3·64 per centum of the resistance of the vessel, *per se*, less than where it is held stationary with its blades behind the stern-post in the vertical position; and 24·24 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel.

(To be continued.)

Erratum.—Page 113, line 4, for steam read stern. The method of raising *steam*, and keeping it up by a floating crane, suggested by this typographical error, is quite happy in obviating all danger from boiler explosions. An originality for this invention is claimed by the compositor of the JOURNAL, and all are warned that a patent cannot be obtained by any other individual.

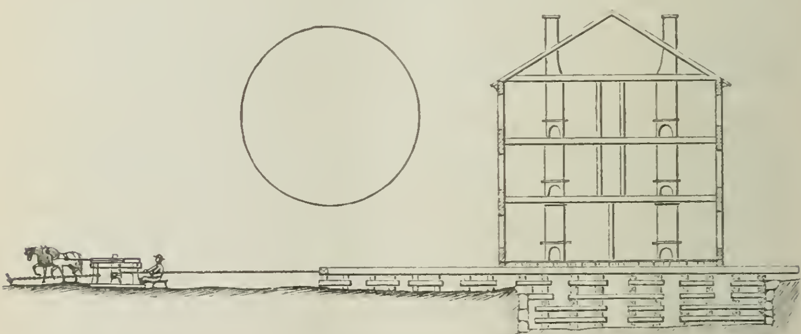
MOVING BRICK HOUSES.

By Charles S. Close.

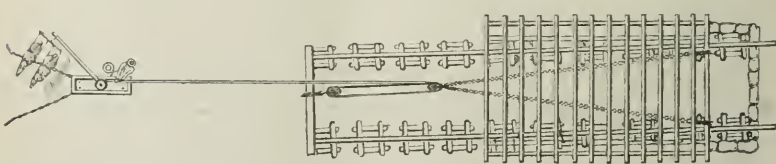
It may interest some of the readers of the Journal to have a short description of the manner of moving brick houses from one location to another, as recently effected in this city.

A good and substantial three-story dwelling, measuring 30 feet by 18 feet on the plan, and about 30 feet height of walls to the eaves, was erected on the farm of Henry Myers, in the southern part of the district of Southwark, about twenty years ago. This building (with a portion of the farm) was recently sold to the Frankford & Southwark Railroad Company. When the company commenced to build their southern terminus depot, they concluded to move the dwelling house to the line of Fifth Street, a distance of nearly four hundred feet.

Sectional Elevation.



Sectional Plan.



The first step was to break holes through the side (9 in.) walls on the level of the under side of the ground floor, between every other pair of floor joists, which were about 16 inches, centre to centre, or 13 inches apart. Through these holes rough yellow pine timbers 12

inches square by about 25 feet long, were inserted, which were thus 2 feet 8 inches, centre to centre. These timbers were brought up into contact with the floor, and keys were driven on top of them to support the side walls. The front and back walls were carried by needles, and two timbers parallel to the cross timbers, were laid in line of the walls, and after blocking up on top of these timbers, the needles were removed. The ends of all the timbers were then braced apart by blocking fitted between each pair, until the whole formed a cradle.

The lifting was effected by jack-screws near the end of each timber, about two feet outside of the walls, fifteen (three nests or sets of five each) on each side. The jack-screws were set tight by one man alone, to ensure equality of strain; after which a man was allotted to each five screws. At the blow of a hammer each man gave a quarter turn to each of his five screws. The raising was two feet lift, and the jack-screws were fleeted three times. A spare screw was applied to the end of the timber, and the working screw relieved, blocking inserted, and then the shortened screw replaced.

A pile of blocking was laid in the cellar and other blocking built on the ground outside and leveled up with cross wedges, and two skids 12 inches square by 60 feet long were laid on the blocking. The cradle was then dropped upon the skids. The upper skid surface and the under side of the cradle were coated with soap. The skids were irregularly placed to suit the convenience of ground or direction, only it was necessary that the distance apart should be such that the chain attachment should work between them.

A long chain sling, ($\frac{3}{4}$ in. or $\frac{7}{8}$ in.), was attached to the last or back timber, so that a pull was placed on all the braces, and the cradle was firmly clamped together. The bight of the chain came under the cradle and was brought to the front and was there hooked into a tackle consisting of a pair of three-fold blocks with 8 inch manilla rope. The second block was hooked to a cross timber which formed a cross-head to the skids, and prevented them being drawn on end. The hauling part of the rope led off to the crab which had a 12 feet bar, to which were attached two horses. The usual spuds held the crab.

The actual moving was at the rate of 2 feet per minute. The whole moving did not occupy two days, but some delay occurred in taking up the stone walls of the old cellar and building the new cellar walls with the material. The course, or path of the moving, was by no means straight, other foundations and irregularities of ground

interfered, and an S path of 50 feet or more deviation was followed. The final position of the house, as left after removal *by the crab*, was within one-fourth an inch of the exact place it should occupy, and this deviation was easily rectified by a jack-screw. The dropping upon the new walls was the reverse of the lifting, except that the screws were applied inside the cellar instead of outside as before.

The great excellence of this operation was its mechanical roughness and simplicity. Everything was convenient, ready and adapted for its work, and seven workmen, well-drilled, all practical laboring men.

DESCRIPTION OF THE PERNOT FURNACE.

Translated from the French of M. Armengaud.

By William F. Durfee, Engineer.

(Continued from Vol. lxx, page 103.)

Works at Fraisans.

M. Vallette, agent of the Franche-Comte Forge Company, assisted at the trials made from the 30th of May to the 4th of June, of the Fraisans pig irons, (used alone or mixed with one-third or two-thirds of gray Rochette pig,) for obtaining puddled iron of ordinary quality. The coal used was of the same quality as in the preceding trials, and consisted of a mixture of small semi-bituminous coal and coal dust in the proportion of one to five. The table (given page 101) shows the results obtained by M. Vallette.

We will remark, that in these several trials, the mixture of the pig iron was constantly changed so as to observe the action of the furnace in the different cases which occur in practice. Thus for the five charges in the first day's work of the furnace, Fraisans No. 3 pig was used alone and produced a granulated puddle-bar. The first three charges of the second day were composed of Fraisans No. 5 pig and gave as a result ordinary puddle-bar; the ninth, seventeenth, nineteenth, and twenty-third charges were composed of one-half

Fraisans No. 3 pig and one-half of gray Rochette pig, and the puddle-bar was granular. The eighteenth was composed of gray Rochette pig alone, the twenty-fourth of one-third Fraisans and two-thirds gray Rochette.

Finally, the twenty-fifth, thirtieth, and thirty-third charges consisted of two-thirds Fraisans No. 3, and one-third gray Rochette, and the thirty-first and thirty-second of the same as the first, of Fraisans No. 3 alone. All these mixtures produced granulated puddle-bar. The coal used for lighting up on the 1st of June was 2·05 tons, which make the total consumed 28·05 tons. To produce one ton (2240 lbs.) of iron, the materials required are as follows:

Pig iron, . . .	2304 lbs.	= 1·029 tons.	
Coal, ...	2050 "	= 0·915 "	not including lighting up.
Hammer-slag, .	179 "	= 0·08 "	
Iron ore, . .	166 "	= 0·074 "	

It is easy to deduce from the foregoing the net cost per ton of the iron obtained.

Blast Furnaces at Montlucon.

MM. Boigues, Rambourg & Co. have also tried their irons in the Pernot furnace. The trials were made in the presence of M. Bonnamy, their engineer and superintendent of manufacture. They had sent to St. Chamond on the 4th of June, 1874, 10915 lbs. = 4·88 tons of very silicious common gray pig iron, which was divided into six charges, five of 1984·5 lbs. and one of 992·25 lbs. There was used 1610 lbs. of iron ore and 88 lbs. of hammer-slag. There was produced in one day and five hours (17 hours) 10315 lbs. = 4·6 tons of granulated puddle bar, the consumption of coal being 9208 lbs. = 4·11 tons, its quality being the same as that heretofore used. The production of puddled bar in 12 hours was 7280 lbs. = 3·25 tons; it would have been 7909 lbs. = 3·34 tons, but for the last charge, for which the Montlucon pig was taken to complete it to 1984·5 lbs.

A ton (2240 lbs.) of puddled bar was produced from 2370 lbs. of gray silicious pig, and 336 lbs. of iron ore, with an expenditure of 2000 lbs. of coal; results which are regarded with great satisfaction when compared with those obtained from the same materials in the common furnace.

The following table shows the time required for working the several charges, and their respective product:

1st charge.	Time 1 h. 55 m.	Weight 1984·5 lbs.	Product 1883 lbs.
2d "	" 2 h. 15 m.	" 1984·5 "	" 1852 "
3d "	" 2 h. 20 m.	" 1984·5 "	" 1872 "
4th "	" 2 h. 35 m.	" 1984·5 "	" 1874 "
5th "	" 2 h. 25 m.	" 1984·5 "	" 1886 "
6th "	" 2 h. 15 m.	" 992·25	" 948 "
		10915 lbs. or 4·88 tons.	10315 lbs. or 4 6 tons.

To complete these statistics which are without doubt interesting to owners of forges in general, we will now give accounts of other trials made with pig irons of different kinds, sent to St. Chamond by the northern works and from those of Belgium.

Ougree Forges.

These works sent one lot of 12480 lbs. = 5·57 tons of white pig iron, and another lot of 27893 lbs. = 12·44 tons of a mixture composed of two-thirds of Ougree spiegel, and one-third of white pig. The following is the result of the working of the first lot:

Ougree White Iron.

1874.	Time.		Charges.	Weight of Iron.	Hammer-Slag.	Coal.	Common Puddle bar.
	Hrs.	Min.		Lbs.	Lbs.	Lbs.	Lbs.
July 15th.	10		5	10,922	684	7,198	9,312
July 17th.	2	30	1	1,558	132	1,343	2,434
Totals.	12	30	6	12,480	816	8,541	11,746 or 5·24 tons.

The above result corresponds to a production of 11276 lbs. = 5 tons in twelve hours. The coal used was the same kind as that in the trial of the Franche-Comte irons. This experiment made in the presence of M. Ghys, engineer of the Ougree Co., resulted in the production of one ton (2240 lbs.) of puddle bar, at an expenditure of 2381·14 lbs. of white pig iron, 135 lbs. of hammer-slag, and 1630 lbs. of coal.

MIXTURE OF ⅔ OUGREE SPIEGEL AND ⅓ WHITE IRON.

July. 1874.	Days' Work.		Charges.	Pig Iron.	Iron Ore.	Hammer-Slag.	Coal.	Puddled Iron.	Quality.
	Hrs.	Min.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
15	5	30	2	3,969		220	3,837	3,883	Raw.
16	10	40	3	5,953	2,029	1,103	4,992	5,797	Common.
16	12	45	4	7,938		661	7,481	7,525	Fibrous.
17	15	10	5	10,033	551	1,058	10,553	9,585	Granular.
Totals.	3 days, 8 hrs.		14	27,893 or 12·44 tons.	2,580	3,042	26,863 or 11·99 tons	26,790 or 11·51 tons	

The production was at the rate of 3·14 tons in twelve hours, and for one ton (2240 lbs.) of puddled bar the quantity of materials used was as follows, viz.: 2423 lbs of the mixed irons, 224 lbs. of iron ore, 264 lbs. of hammer-slag, and 2334 lbs. of coal. The trials of the iron produced for the purpose of ascertaining its tensile strength, resulted as follows:

	1st test.	2d test.
Breaking strain per square inch, ...	55,555 lbs.	55,555 lbs.
Per cent. of elongation before rupture,	19·5 per cent.	20 per cent.

FORGES OF THE JOHN COCKERILL COMPANY.

The great establishment, at Seraing, sent in August, 1874, 22040 lbs. (9·83 tons) of white pig iron, intended for conversion into pud-

dled iron to be used for rail-heads. The trials of this iron were made in the presence of M. Wattieux, engineer of the company, and charges of 2205 lbs. (1000 kil.) each, with an average addition of 110 lbs. of hammer-slag, and there was obtained in 27 hours, 20698 lbs. (9·24 tons) of puddled bar, which was at the rate of 4·1 tons in twelve hours. The consumption of coal, which was of the same quality as that used in previous trials, was at the rate of 1640 lbs. per ton of iron produced.

Works of MM. Michel Helson & Co., at Haumont.

These works sent in September, 1875, 22040 lbs. (9·83 tons) of white pig iron, which was treated in ten charges, with the addition of 132 lbs. of hammer-slag to each charge, and resulted in the production of 20663 lbs. (9·22 tons of ordinary rough puddle bar in 27 hours, which corresponds to a production of 4·09 tons in one day of twelve hours. We will here remark, that it was not necessary to repair the movable bottom of the furnace during the treatment of these ten charges, and consequently it was not necessary to use any iron ore. The coal consumed was at the rate of 1724 lbs. per ton of iron obtained.

Works of MM. Gouvy Brothers, at Dieulourd.

M. Girard, engineer and superintendent of these works, sent to St. Chamond pig irons of various qualities, which were mixed in certain proportions with a view to the production of puddled steel. These mixtures were composed as follows:

Kind of Pig Iron.	Mixture A.	Mixture B.	Mixture C.
Gray, No. 1, . . .	220 lbs.		
" " 2, . . .	430 "	301 lbs.	141 lbs.
" " 5, . . .	421 "	743 "	963 "
English, ...	119 "	119 "	139 "
Spiegel, ...	181 "	181 "	101 "
Totals, . . .	1344	1344	1344

Results of Trials of the above Mixtures in the Pernot Furnace.

September 1874.	Days' Work of Furnace.		Number of Charges.	Quality of Pig Iron.	Quantity of			Consumption.		Product of Puddled Steel.
					Pig Iron.	Iron Ore.	Roll Scale	Hammer Slag	Coal.	
	Hrs.	Min.			Lbs.	Lbs.	Lbs.		Lbs.	Lbs.
9	2	30	1	No. 1.	1,345	"	"	St. Chamond	1,343	1,296
10			2	"	1,345	"	"	Gouvy.		1,226
10			3	No. 2.	1.347	"	"	"		1.283
10	13	20	4	"	1,345	"	"	"	7.097	1,213
10			5	½ No.1, ½ No.2	1,345	"	"	"		1,360
10			6	Mixture A.	1,347	"	"	"		1,310
11			7	"	1,347	"	"	"		1,296
11			8	"	1,345	"	"	"		1,274
11	10	20	9	"	1,347	"	"	"	5,907	1,341
11			10	"	1,347	"	"	"		1,349
11	2	10	Repairing the bottom.			1,543	441		959	
12			11	Mixture A.	1,347	"	"	"		1,257
12	9	10	12	" B.	1,347	"	"	"	5,907	1,268
12			13	" "	1,345	"	"	"		1,259
12			14	" C.	1,367	"	"	"		1.239
Total	37 hrs.	30 min.			18,846 or 8·41 tons.	1,543	441		21,213 or 9·47 tons.	17,970 or 8·04 tons.

For the first charge, the hammer-slag of St. Chamond was used, but for the thirteen following charges the slag from the refining fires of MM. Gouvy was employed. The mean production was at the rate of 2·57 tons in twelve hours. To produce one ton (2240 lbs.) of puddled steel, required 2344 lbs. of pig iron and a consumption of 2638 lbs. of coal.

Conclusions.

From all the foregoing facts we should conclude that the problem of mechanical puddling had been solved in a most satisfactory manner by the system invented by M. Pernot, in fact, with this furnace, the best quality of iron can be produced with more regularity, less loss, and in much greater quantity, than is possible in the old method,

and there is also an important economy in labor, as well as in the consumption of coal and scrap.

In short, we may now be assured that the Pernot process is in every way a practical success. Further experimental trials are unnecessary, for as a method of manufacture fully perfected, we can obtain easily and surely the different products which are produced in a puddling furnace, whether fibrous iron, common iron, or puddled steel.

We mention, finally, a consideration which will not fail to be of interest, it is the good feeling and alacrity with which the workmen have adapted themselves to the experiments, they have understood the consequences from the first, that they would naturally profit from their point of view by the ease and relief in the laborious work of puddling afforded by the new apparatus.

PERNOT FURNACE.—APPLIED TO THE MANUFACTURE OF STEEL.

The remarkable results of the new method of puddling which we have examined, have induced the inventor, encouraged moreover by MM Petin & Gaudet, to adapt his furnace to the manufacture of cast steel by the use of gaseous fuel produced and employed by means of the generators and re-generators of M. Siemens, the application of which to the melting of steel in furnaces with fixed bottoms was the idea of M. Martin, and has been effected in a furnace designed by M. Siemens.

The Pernot process, by its special peculiarity of the rotation of the inclined movable bottom, gives great heat and rapid decarbonization, and thus so far modifies the conditions under which the steel is melted that they have no great similarity to those of the old methods.

The gas generators are of the same dimensions as those employed in the Siemens-Martin furnace, but they produce in the same time, three or four times more steel when they are applied to the Pernot system, which not only reduces the expense of fuel, but, what is more important, realizes a great economy in labor, moving power, first cost of erecting plant, and in general expenses. "These results alone, (we quote from the paper read before the Society of Civil Engineers), would ensure the success of such a process, but, the capabilities of the mode of working have much more influence, operations impossible in the old furnaces, being accomplished without difficulty

in this." "By means of this furnace, we can operate upon gray pig iron, without the addition of any scrap iron or scrap steel, and transform it directly into melted wrought iron, which is recarburized by the addition of spiegel, as in the Bessemer process, and is then cast into perfectly malleable steel, which will make excellent rails; the similarity of the chemical reactions to those of the Bessemer process is very great. We also succeed perfectly in casting the steel for rails, without the further addition of pig iron, and the entire operation requires from seven to eight hours for a charge of from nine to eleven thousand pounds."

We will now briefly describe the construction of the furnace for melting with gas which is erected and in use in the new shops at St. Chamond, and will afterwards speak of the advantages which it presents.

Description of a Furnace for Steel.—See Plate.

Fig. 1 shows a side elevation of the furnace and its movable bottom, as seen from the rear.

Fig. 2 is a longitudinal vertical section of the apparatus along the lines 1–2–3–4 of the plan as seen in Fig. 3.

Fig. 3 represents in one part a horizontal at the height of the line 5–6, (Fig. 2), above the movable bottom, and in the other part, a similar section on the line 7–8, (Fig. 2), above the two chambers of the regenerators.

Fig. 4 is a transverse vertical section passing through the axis on line 9–10, (Fig. 2.)

These figures are drawn to a scale, and show the dimensions of a furnace for the production of four or five tons of steel at one time. They show that the apparatus is arranged in a manner similar to that of the puddling furnace we have before described, it has the same "pot" or turning bottom actuated by a small steam engine, but it is heated by the Siemens' method. It is not necessary to give a particular description of this method here, as its successful application and the details of its construction are well known to our readers. The inspection of the Figs. 2, 3 and 4 allows us to examine that which is beneath the furnace proper, and shows the existence of four chambers, R^1, R^2, R^3, R^4, filled with fire-brick, separated from one another so as to permit the

entrance and free passage of the air or the gas which constitutes the gaseous fuel.

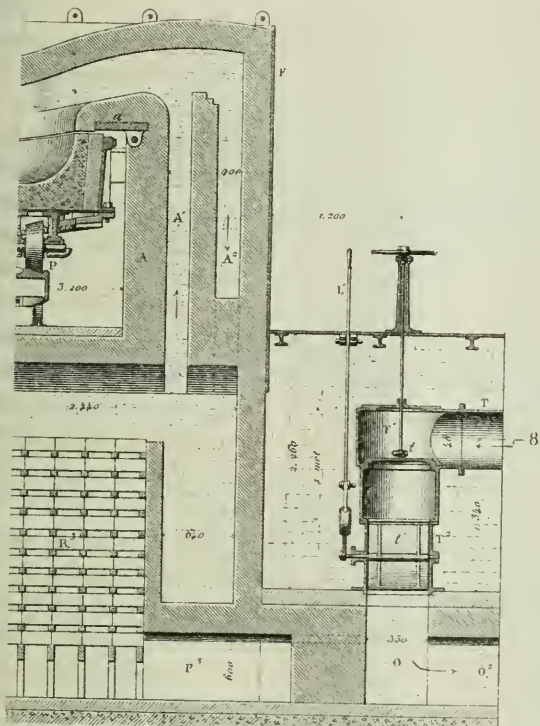
This last arrives from the generators by the pipes T in the two cast iron boxes T′, each containing a closing valve, *t*, and a reversing valve, *t*′, which is worked by means of the hand lever, L′, and directs alternately and methodically the gas into the regenerators R^3 and R^4 on the one side, and into those marked R^1, R^2 on the other side. We notice, also, that each of the valve boxes is placed above the opening, O^1, which communicates with the chimney flue, O^2, and has at its base a chest, T^2, (Fig. 3), which covers the openings o^1 and o^2, by which it communicates with the flues, P^3 and P^4. These arrangements are designed to direct, for a certain time, the gas and air destined to enter into combustion in the furnace, whilst the two other regenerators are heated by the products of this combustion passing in an inverse direction; when these last two have been sufficiently heated, we reverse the valves t^1 for changing the directions of the currents of gas and air, which produces a similar effect as before, but in an inverse direction.

The mode of heating the furnace proper differs little from that which has been described; under the roof, C, in the piers, A, are placed the flues, A^1 and A^2, for the ingress and egress of the gas and air by the large openings which permit a free passage to the inclined "pot," H, on its carriage, R, which is able to enter and leave the furnace freely and easily on the rails, S.

The "pot" is made to rotate by means of a steam engine, O, which, by the wheel, M, and the pinions, N and L, actuates the bevel gear, K, fixed under the bottom of the envelope which is pierced with holes for the purpose of cooling when necessary in the same way as in the puddling furnace. The furnace is provided with a working opening, *c*, closed by the hanging door, *d*, and the "pot" is provided with a tap-hole, *h*, which when open affords a passage for the cast steel to the ladle, V, by means of the gutter, U.

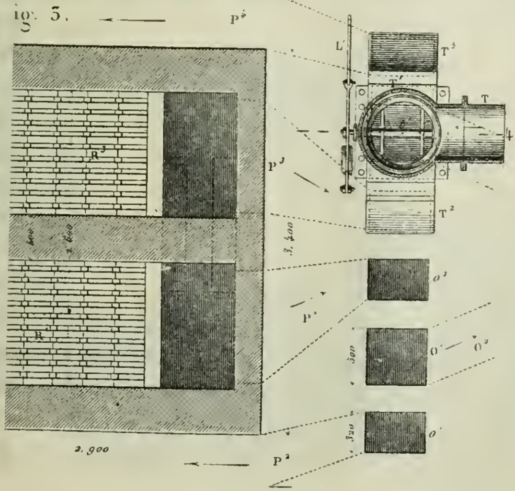
The ladle is placed as in the Bessemer process (which we have described in vols. xiv and xv) in the interior of a large pit, F^1, 15 or 18 feet in diameter; at the same distance from circumference of the pit, as the tap-hole, *v*, are arranged in a circle, close to one another, the ingot moulds, which are put in place and removed, by the aid of an over-head crane with a radial arm having its point of suspension directly over the centre of the pit, and, consequently above the

2.



F
A'
A
A²
P
3.200
1.200
L'
T
T'
8
R³
P³
600
330
O
O²

ig. 3.



P⁴
L'
T³
T
T²
4
P³
R³
R¹
3.400
O¹
O²
500
320
2.900
P²

Pernot Furnace for melting 4 to 5 Tons of Steel per charge

Fig. 4

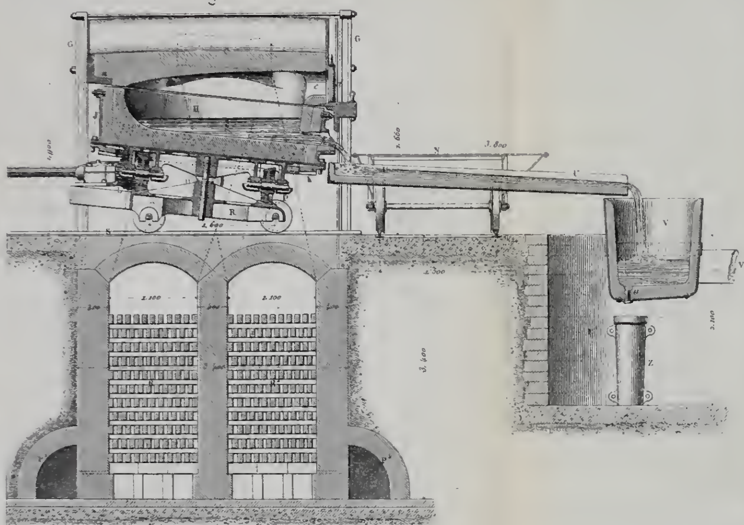


Fig. 2

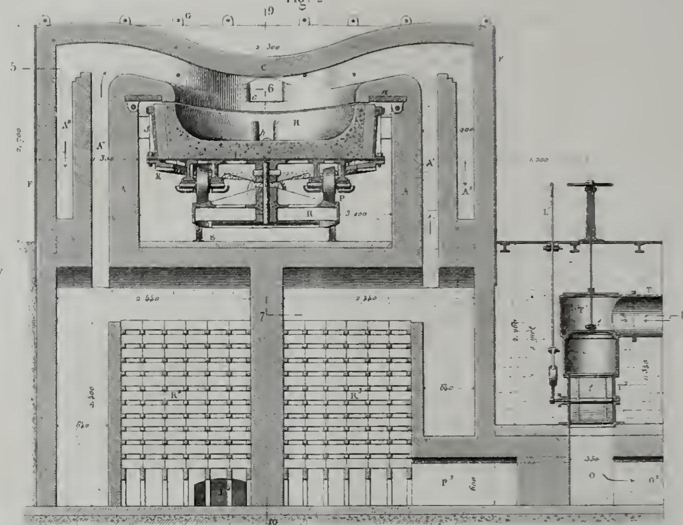


Fig. 1

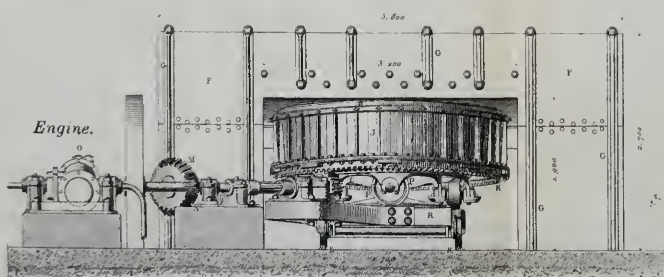
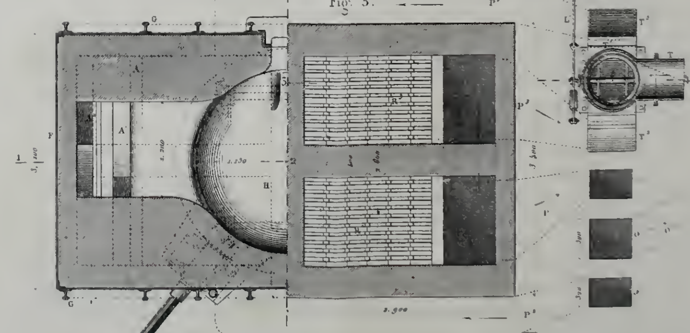


Fig. 5.



buried pivot which supports the arm, V^1, of the ladle, V. By this means the successive removals of all the moulds is accomplished with great promptness and facility, and without inconvenience to the other operations.

MANAGEMENT OE THE APPARATUS.

We will state at the outset, that the bottom is made of siliceous sand, reheated and annealed. As soon as the furnace is sufficiently hot, we immediately charge the quantity of pig iron necessary to form a proper bath, say, for example, from one to one and one-half tons. To distribute this quantity uniformly over the bottom is an operation simple and easy, by causing the "pot" to rotate, and successively present all parts of the charge before the working doors. After the distribution, the iron is exposed to a high temperature and soon becomes liquid; we introduce then, in the same way, the remainder of the charge, consisting of either scrap iron, crop ends of steel, and old rails, which may be used if they are not more than three or three and one-half feet long; we can effect this charging cold; and at one time, or, what is better, in parts, the pieces of metal being previously heated to a red heat in an ordinary furnace; by this means we do not cool the bath. In consequence of the mobility of the bottom, the heat penetrates regularly through the whole of the mass and the pieces of metal as they are successively immersed in the bath augment its volume.

It is worthy of note that this immersion being complete, the pig iron, wrought scrap, and the rails, do not become burned, which is inevitable in a furnace with a fixed bottom, if we charge too much at a time, that is to say, more than the bath will properly cover. Charging the whole of the materials at once has the advantage of diminishing the number of men employed at the furnace, for, we have not so much detail to the labor, and they can be employed at other work as soon as the charge is completed.

When this is accomplished the working door is closed and the heat increased, the "pot" being turned at the rate of two or three revolutions per minute. The charge is melted in from two to three hours, and soon after we commence to take what is called the "tests" in order to ascertain the degree of decarburization. It appears necessary to explain briefly the method of making the "test," which is accomplished without retarding the operation, enabling the woikmen

in charge of the furnace to proceed with entire confidence. Having observed this operation with great care and attention, we may be allowed to speak of it with confidence.

There is generally two tests, the first is taken as soon as the whole of the mass is completely melted and decarbonized. We then, by means of a long handled ladle or spoon, take a small quantity of the melted material, two pounds for example, which, after it solidifies, we take to a steam-hammer and form it into a sort of flat and round cake, three or four inches in diameter, and not over three-eighths of an inch thick. We cool this disc by dipping it in a vessel of water, and we then place it on an angular groove cut in a steel block, and by striking it in the middle it is made to bend and finally to break into two parts. Under the action of the hammer there is formed on the circumference of the disc a great number of cracks, which are certain indications to the workman of the character of the metal.

According as the "test" bends with more or less ease before it is broken, it is judged that the metal requires more or less wrought iron, and if it is fractured easily, it is evident that the metal is brittle rather than tough. This "test" allows us to correct the charge and to determine the quantity of "spiegel," that is to say, the manganiferous pig iron which it is necessary to add to the fused mass in order to give it the degree of carburization suited to the nature of the steel we desire to obtain. Thus in practice, when the mass has too much wrought iron, we use, to correct it, as much as eight or nine per cent. of "spiegel," or 1000 lbs. for every 9000 lbs. of the melted mass contained in the "pot." In the contrary case we add but four or five per cent. of "spiegel."

The pigs of "spiegel" after having been weighed are heated in a neighboring furnace (as was the wrought iron) and carried on a car, X, (Fig. 4), to the melting furnace. The men stand on the car with forks, and throw into the furnace all the "spiegel" as rapidly as possible, which is immediately received and drowned in the fused bath, the heat of which is maintained and its turning continued. After ten or twelve minutes the whole of the "spiegel" is completely melted. We now make the second "test" by taking a small quantity of metal and proceeding as before, submit it to a steam-hammer and form it into a disc, which does not present the same aspect as the first, but instead of its edges being cracked, they are, on the contrary, very smooth, without cracks, and after cooling, it is broken at the angular groove

by one blow on the "sett," the fracture showing a homogeneous grain very fine and close.

During this last "test," which requires two or three minutes, the furnace continues its movement, which has not been interrupted during the heat, except when the workmen examined and prepared the tap-hole. When ordered, the men remove the stopper from the tap-hole in the side of the "pot," and the liquid metal flows through the gutter, U, (which is lined with fire-clay) into the large ladle, V, which has been previously heated. This ladle is of sufficient capacity to contain from 9 to 11,000 lbs. of melted metal.

After the tapping, nothing remains in the bottom and as we never find in the Pernot furnace, as in the furnaces with fixed bottoms, pieces of rails which are not melted, or lumps of metal adhering to the sides, the delay to the process after this operation is very short, and after beating the bottom a little we re-charge immediately. The duration of an operation, including the charging and repairs, is but four or five hours at most, for a charge of nine thousand pounds. The daily product at the works of St. Chamond is twenty tons of steel in twenty-four hours, and we think this will be exceeded when the working force is properly trained. Besides we must observe that this is not the limit to the dimensions of the apparatus or to the production, for at the time of our visit we saw a new furnace built on the same idea which is capable of receiving charges of ten tons.

From the first day this furnace was fired it worked satisfactorily, and accomplished with certainty the results which were hoped for, four tappings being made in twenty-four hours, which corresponds to a product of 40 tons per day, or $40 \times 300 = 12000$ tons per year. For a furnace of this capacity, it is sufficient to increase the diameter of the "pot" two feet, and it is worthy of remark that the heating apparatus is exactly the same as in the furnace represented n the Plate, and offers the same advantage in saving fuel.

This is explained by the fact that the surface exposed to the flame is considerable in proportion to the small thickness of the layer of metal which is continually presented to its action. If we have a circular "pot" ten feet in diameter, the area of its section is 78·5 square feet. But ten tons of pig iron and scrap at a mean weight of 437 lbs. per cubic foot forms a volume of 51·5 cubic feet, and consequently occupies a depth of about eight inches in the "pot."

For the five ton furnace, the diameter of the "pot" is 8 feet 3 inches, and the surface in contact with the gas is about 53·5 square feet, and the volume of the metal is about 25·6 cubic feet, hence its thickness is about 5½ inches; it is certain that the dimensions given of the gas generators are more than sufficient; as we have said, they are similar to those adopted by M. Martin for his furnace with a fixed bottom, and they are capable of furnishing the heat necessary for an apparatus very much larger.

Advantages of the System.

As we have demonstrated in regard to the puddling, so the advantages of the application of the new furnace of M. Pernot to the manufacture of steel are very marked and consist of:

1st. A considerable increase of the production, since an apparatus of 8 feet 3 inches in diameter, receiving charges of four or five tons, will easily turn out 20 tons in 24 hours, while the Siemens–Martin furnace will not produce more than 10 tons in that time.

2d. A reduction of some importance in the amount of the labor, fuel, general expenses, and cost of repairs.

3d. A considerable economy in the net cost, since after the first trials were made, during a period of three weeks, with materials costing $31.32 per ton, the mean net cost of product according to the books of MM. Petin & Gaudet, appears to be $43.02 per ton, whilst with the same materials used in the Siemens–Martin furnace, the net cost becomes $50.90.

4th. The repairs of the roof and other parts of the furnace are easily and rapidly accomplished. Owing to the mobility of the car, we can remove the "pot" from the furnace, and the enormous opening which it leaves allows us freely to enter and make repairs after the expiration of a few hours, which are necessary for cooling. In ten hours the workmen make an entire roof, and if greater repairs are necessary, one day will probably be sufficient for making them, and re-heating the furnace. This is very advantageous as the routine of the works is but slightly interrupted.

5th. The first cost considered relative to the production is small. In fact, according to the paper presented by M. J. Petin to the Society of Civil Engineers, the cost of a Pernot furnace, for converting at one operation four or five tons of metal into steel, is placed at $7688·00, but three furnaces, capable of melting together 60 or

eighty tons in 24 hours, are sufficient to replace two Bessemer converters requiring an outlay of more than $60,000.

6th. The operation can always be modified in various ways up to the time of tapping, which is a great advantage, and one not possessed by the Bessemer process.

7th. The steel is perfectly homogeneous, owing to the mixing of the metal produced by the rotation of the "pot" this saves the stirring by hand and consequently the use of tools.

8th. Finally, the Pernot process is applied with the same success to a small as to a large production without requiring in any case the erection and maintenance of the gigantic machinery which characterizes the Bessemer process.

CARILLON MACHINE.*

Most of our readers have heard church bells play tunes. At one period such an arrangement was very common, and on the Continent of Europe the system was brought to considerable perfection; but in England the results obtained were not satisfactory, and it is only within a recent period that the employment of machinery for the production of airs from church bells has become popular. The progress of the movement is due, beyond question, to Messrs. Gillett and Bland, of Croydon. These gentlemen manufacture clocks on a very large scale, and they have devoted much attention to the improvement of carillon machinery, and have achieved great success.

As the method of producing tunes from church bells is but little understood, it will be well to preface our description of the machine we illustrate by a few words of explanation.

Church bells are caused to sound in two ways—either, that is to say, by swinging them, and so causing the clappers to strike them; or by the aid of hammers of various weights according to the size of the bell, caused to rise and suffered to fall on the bell. Peals are rung by hand, the bells being swung; clocks always strike the bell with a

* From the *Engineer*, London, Aug. 13, 1875.

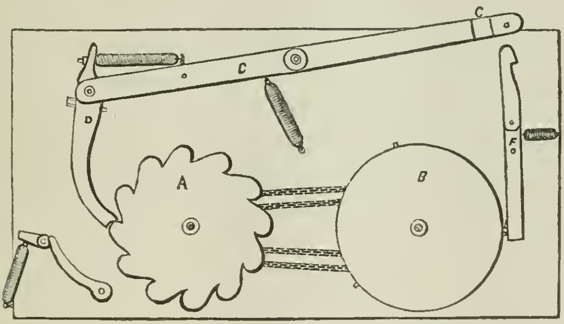
hammer, the bell being at rest. The hammer is raised by a wire, which pulls down the hammer tail, the wire being worked by a lever, the end of which is caught by a cam on a revolving barrel in the clock below. It is obvious that if a number of bells are all fitted with hammers, and the number of cams is sufficiently great, and the cams are properly arranged, that a tune can be played by a mere multiplication of the device by which a clock is made to strike the hours on a single bell.

The carillon machine embodies this arrangement, only instead of cams, a number of short pins are set in a revolving barrel, and these pins catch the toes of levers connected by wires with the hammer tails in the bell chamber above. The pins are set or "pricked in precisely in the same way as the little points in the barrel of a musical box. If our readers will bear the musical box in mind, and fancy that the whole is enormously enlarged, and that the toes of the levers take the place of the springs, the arrangement will be quite clear. Such is the old-fashioned, or, as we may term it, "positive," carillon machine; and its defects are very serious.

In the first place, after the hammer has been suffered to fall, it can only be lifted by the rotation of the barrel, and as the time of dropping the hammer depends entirely on the rotation of the barrel, it is obvious that the barrel can only revolve at a slow speed, and, consequently, much time is lost in lifting the hammer. The result is that a rapid musical passage cannot possibly be performed. The weight of a hammer for a large bell is sometimes as much as 3 cwt., while that for a small bell may not be one-fourth of this; but the musical barrel always has the same propelling force, and the result is that when the small bells, or high notes, come to be played in any tune, the barrel meets with less resistance, and revolves faster than when it has to deal with the deep notes and large bells. It follows that the air is played out of time. Lastly, the barrel must be of great size, weight and strength to do the work.

All these difficulties are overcome by the invention of Messrs. Gillett and Bland illustrated in the diagram—which explains a principle, and not details. This principle we may call "negative." The hammers are always kept raised, and are only allowed to drop by the agency of the musical barrel. The instant they fall they are lifted again, and so long as the lifting is accomplished quickly enough, the time of lifting has nothing to do with the production of the air. That is de-

termined solely by the musical barrel, which, being relieved of the work of lifting, has little or no strain on it, can be made small and light, and will always revolve at the same rate, and so insure that the tune shall be played in perfect time. It also follows that the most rapid passages can be played with the greatest ease and precision.



The diagram is supposed to show the gear for working one hammer. It must be multiplied in proportion to the number of hammers, but the parts are all repetitions of each other. It will be understood that the diagram does not show details, but simply illustrates a principle.

The musical barrel B is set with pins in the usual way. A is a cam wheel of very peculiar construction, operating a lever C by what is to all intents and purposes, a new mechanical motion, the peculiarity of which is that, however fast the cam wheel revolves, the tripping of the lever is avoided. In all cases the outer end must be lifted to its full height before the swinging piece D quits the cam. The little spring roller E directs the tail D of the lever into the cam space, and when there it is prevented from coming out again by a very simple and elegant little device, which Messrs. Gillet and Bland do not at present desire to be made public, by which certainty of action is secured. At the other end of the lever C is a trip lever F. This lever is pulled toward C by a spring, and whenever C is thrown up by the cam wheel, F seizes it and holds it up; but the wire to the bell hammer in the tower above is secured to the eye G, so that when D is lifted, the eye G being pulled down, the hammer is lifted. The pins in the musical barrel B come against a step in F, and as they pass by they push F outwards and release C, which immediately drops, and with it the hammer, so that the instant a pin passes the step F a note is sounded. But the moment D drops it engages with A, which last

revolves at a very high speed, and D is incontinently flung up again, and the hammer raised, and raised it remains until the next pin on B passes the step on F, and again a note is struck. It will be seen, therefore, that, if we may use the phrase, B has nothing to do but let off traps set continually by A, and so long as A sets the traps fast enough, B will let them off in correct time. But A revolves so fast and acts so powerfully, that it makes nothing of even a 3 cwt. hammer, much less the little ones; and thus Messrs. Gillett and Bland obtain a facility of execution heretofore unknown in carillon machinery. A Carillon Machine can be actuated not only by means of the barrel B, but can have a key-board, same as for a piano-forte, so that any musician can play tunes as easily as played on a piano-forte or an organ.

THE PROPOSED INLAND SEA IN ALGERIA.

Some time since a project was conceived by Captain Roudaire, of the French Navy, to fill the immense depressions, which are known under the name of "chotts," with water from the Mediterranean. The subject attracted great attention, and was brought before the Academy of Sciences by M. de Lesseps.

After some discussion, during which many objections were raised against the project, an expedition, headed by Captain Roudaire, was appointed to take the levels of the region of the chotts, in order to determine the extent of the area which was capable of being submerged. The expedition included two captains and a lieutenant of the Etat Major, an infantry captain, a surgeon-major, M. Duvegrier, deputed by the Geographical Society of France, and a young mining engineer. The expedition has completed its work, and M. de Lesseps has reported upon it to the Academy.

The operations continued without a breach for more than four months, the entire tour of the chotts having been made, and El Oued and Négrine connected by a transverse profile, the whole making a distance of 650 kilometers. The result is that the depression capable of being flooded in Algeria forms an area of 6,000 square kilometers, included within 34·38° and 33·51° north latitude, and 4·51° and 3·40° east longitude. In the central portion the depression varies from 20 to 27 meters below the sea level.

None of the fine oases of the Souf would be immerged by the inletting of the sea, the lowest of them, Debila, being 58 meters above the sea. In the Oued-Rhir, the two unimportant oases of Necira and Deudonga would alone be submerged.

It was suggested that the presence of the salt-water would affect the wells which fertilize the oases, but M. Roudaire affirms that he found that all the wells, even those nearest to the basin to be inundated, were fed by a source of water higher than the sea level.

The expedition not being able to cross the Tusinian frontier, were only able to examine the western end of the chott Rharsa, but they ascertained that it was also below the level of the Mediterranean, and had an incline of about 2·20 meters per kilometer towards the Gulf of Gabés.

The basins of the chott Rharsa and chott Melrir, although connected by the chott El-Asloudj, are not now in direct communication, for the last-named chott has an altitude of 3·20 meters in its central part, and is, moreover, bounded on the east and west by a chain of dunes. These dunes of Bou-Douil and of Zeninim may be easily cut through at passes of which the greatest altitude does not exceed 6 to 7 meters; the distance to excavate would be 20 kilometers. It is suggested that the chott Rharsa might first be inundated, and then a communication being made with chott Melrir by a cutting, the sea would soon open it to the necessary size and depth.

A great question remains yet to be answered, namely, the amount of difficulty there would be in cutting through the Isthmus of Gabés. Opinion differs upon this point. M. Fuchs, a mining engineer, who has explored the region, gives the Isthmus a relief of 40 to 50 meters, but his levels were only taken with an aneroid barometer, and at points, so that the question is still open.

At the present moment an Italian Commission is taking levels in that part, and when the results of their labors are known, the cost of piercing this isthmus, and the possibility in an economical point of view of carrying out his stupendous project of an inland sea, will be determined.

The existence of the vast depression, which some persons dispute, is considered to be placed beyond all question by the observations of Captain Roudaire and his associates.—*Journal of the Society of Arts.*

Chemistry, Physics, Technology, etc.

PRELIMINARY NOTICE OF FURTHER RESEARCHES ON THE PHYSICAL PROPERTIES OF MATTER IN THE LIQUID AND GASEOUS STATES UNDER VARIED CONDITIONS OF PRESSURE AND TEMPERATURE.*

By Dr. Andrews, F. R. S., Vice-President of Queen's College, Belfast.

The investigation to which this note refers has occupied me, with little intermission, since my former communication in 1869 to the Society, "On the Continuity of the Liquid and Gaseous States of Matter." It was undertaken chiefly to ascertain the modifications which the three great laws discovered respectively by Boyle, Gay-Lussac, and Dalton undergo when matter in the gaseous state is placed under physical conditions differing greatly from any hitherto within the reach of observation. It embraces a large number of experiments of precision, performed at different temperatures and at pressures ranging from 12 to nearly 300 atmospheres. The apparatus employed is, in all its essential parts, similar to that described in the paper referred to; and so perfectly did it act, that the readings of the cathetometer, at the highest pressures and temperatures employed, were made with the same ease and accuracy as if the object of the experiment had been merely to determine the tension of aqueous vapor in a barometer tube. In using it the chief improvement I made is in the method of ascertaining the original volumes of the gases before compression, which can now be known with much less labor and greater accuracy than by the method I formerly described. The lower ends of the glass tubes containing the gases dip into small mercurial reservoirs formed of thin glass tubes, which rest on ledges within the apparatus. The arrangement has prevented many failures in screwing up the apparatus, and has given more precision to the measurements. A great improvement has also been made in the

* A paper read before the Royal Society.

method of preparing the leather washers used in the packing for the fine screws, by means of which the pressure is obtained. It consists in saturating the leather with grease by heating it *in vacuo* under melted lard. In this way, the air enclosed within the pores of the leather is removed without the use of water, and a packing is obtained so perfect that it appears, as far as my experience goes, never to fail, provided it is used in a vessel filled with water. It is remarkable, however, that the same packing, when an apparatus specially constructed for the purpose of forged iron was filled with mercury, always yielded, even at a pressure of 40 atmospheres, in the course of a few days.

It is with regret that I am still obliged to give the pressures in atmospheres, as indicated by an air or hydrogen manometer, without attempting for the present to apply the corrections required to reduce them to true pressures. The only satisfactory method of obtaining these corrections would be to compare the indications of the manometer with those of a column of mercury of the requisite length; and this method, as is known, was employed by Arago and Dulong, and afterwards in his classical researches by Regnault, for pressures reaching nearly to 30 atmospheres. For this moderate pressure, a column of mercury about 23 meters or 75 feet in length, had to be employed. For pressures corresponding to 500 atmospheres, at which I have no difficulty in working with my apparatus, a mercurial column of the enormous height of 380 meters, or 1250 feet, would be required. Although the mechanical difficulties in the construction of a long tube for this purpose are, perhaps, not insuperable, it could only be mounted in front of some rare mountain escarpment, where it would be practically impossible to conduct a long series of delicate experiments. About three years ago, I had the honor of submitting to the Council of the Society a proposal for constructing an apparatus which would have enabled any pressure to be measured by the successive additions of the pressure of a column of mercury at a fixed length; and working drawings of the apparatus were prepared by Mr. J. Cumine, whose services I am glad to have again this opportunity of acknowledging. An unexpected difficulty, however, arose in consequence of the packing of the screws (as I have already stated) not holding when the leather was in contact with mercury instead of water, and the apparatus was not constructed. For two years the problem appeared, if not theoretically, to be prac-

tically impossible of solution; but I am glad now to be able to announce to the Society that another method, simpler in principle, and free from the objections to which I have referred, has lately suggested itself to me, by means of which it will, I fully expect, be possible to determine the rate of compressibility of hydrogen or other gas by direct reference to the weight of a liquid column, or rather of a number of liquid columns, up to pressure of 500 or even 1000 atmospheres. For the present, it must be understood that in stating the following results, the pressures in atmospheres are deduced from the apparent compressibility in some cases of air, in others of hydrogen gas contained in capillary glass tubes.

In this notice I will only refer to the results of experiments upon carbonic acid gas, when alone or when mixed with nitrogen. It is with carbonic acid, indeed, that I have hitherto chiefly worked, as it is singularly well adapted for experiment: and the properties it exhibits will doubtless, in their main features, be found to represent those of other gaseous bodies at corresponding temperatures below and above their critical points.

Liquefaction of Carbonic Acid Gas.—The following results have been obtained from a number of very careful experiments, and give, it is believed, the pressures, as measured by an air-manometer, at which carbonic acid liquefies for the temperatures stated:

Temperatures in Centigrade Degrees.	Pressure in Atmospheres.
0·00	35·04
5·45	40·44
11·45	47·04
16·92	53·77
22·22	61·13
25·39	65·78
28·30	70·39

I have been gratified to find that the two results (for 13·09° and 21·46°) recorded in my former paper are in close agreement with these later experiments. On the other hand, the pressures I have found are lower than those given by Regnault as the results of his elaborate investigation (*Mémoires de l'Académie des Sciences*, vol. xxvi, p. 618). The method employed by that distinguished physicist was, not, however, fitted to give accurately the pressures at which carbonic acid gas liquefies. It gave, indeed, the pressures exercised

by the liquid when contained in large quantity in a Thilorier's reservoir; but these pressures are always considerably in excess of the true pressures, in consequence of the unavoidable presence of a small quantity of compressed air, although the greatest precautions may have been taken in filling the apparatus. Even $\frac{1}{500}$th part of air will exercise a serious disturbing influence when the reservoir contains a notable quantity of liquid.

Law of Boyle.—The large deviations in the case of carbonic acid at high pressures from this law appeared distinctly from several of the results given in my former paper. I have now finished a long series of experiments on its compressibility at the respective temperatures of 6·7°, 63·7°, and 100° C. The two latter temperatures were obtained by passing the vapors of pyroxylic spirit (methyl-alcohol) and of water into the rectangular case with plate-glass sides, in which the tube containing the carbonic acid is placed. The temperature of the vapor of the pyroxylic spirit was observed by an accurate thermometer, whose indications were corrected for the unequal expansion of the mercury: while that of the vapor of water was deduced from the pressure as given by the height of the barometer and a water-gauge attached to the apparatus. At the lower temperature (6·7°), the range of pressure which could be applied was limited by the occurrence of liquefaction; but at the higher temperatures, which were considerably above the critical point of carbonic acid, there was no limit of this kind, and the pressures were carried as far as 223 atmospheres. I have only given a few of the results; but they will be sufficient to show the general effects of the pressure. In the following tables p designates the pressure in atmospheres as given by the air manometer, t' the temperature of the carbonic acid, e the ratio of the volume of the carbonic acid under one atmosphere and at the temperature t' to its volume under the pressure p' and at the same temperature, and θ the volume to which one volume of carbonic acid gas measured at 0° and 760 millimetres is reduced at the pressure p and temperature t':

Carbonic Acid at 6·7°.

p.	t'	e.	θ.
Atmospheres.	Degrees.		
13·22	6·90	$\frac{1}{14 \cdot 36}$	0·07143

20·10	6·79	$\frac{1}{23{\cdot}01}$	0·44456
24·81	6·73	$\frac{1}{29{\cdot}60}$	0.03462
31·06	6·62	$\frac{1}{39{\cdot}57}$	0·02589
40·11	6·59	$\frac{1}{58{\cdot}40}$	0·01754

Carbonic Acid at 63·7°.

p. Atmospheres.	*t′* Degrees.	*e.*	*θ.*
16·96	63·97	$\frac{1}{17{\cdot}85}$	0·06931
54·33	63·57	$\frac{1}{66{\cdot}06}$	0·01871
106·88	63·75	$\frac{1}{185{\cdot}90}$	0·00665
145·54	63·70	$\frac{1}{327{\cdot}30}$	0·00378
222·92	63·82	$\frac{1}{446{\cdot}90}$	0·00277

Carbonic Acid at 100°.

p. Atmospheres.	*t′* Degrees.	*e.*	*θ.*
16·80	100·38	$\frac{1}{17{\cdot}33}$	0·07914
53·81	100·33	$\frac{1}{60{\cdot}22}$	0·02278
105·69	100·37	$\frac{1}{137{\cdot}10}$	0·01001
145·44	99·46	$\frac{1}{218{\cdot}90}$	0.00625

223·57	99·44	$\frac{1}{380·90}$	0·00359

These results fully confirm the conclusions which I formerly deduced from the behavior of carbonic acid at 48°, viz., that while the curve representing its volume under different pressures approximates more nearly to that of a perfect gas as the temperature is higher, the contraction is nevertheless greater than it would be if the law of Boyle held good, at least for any temperature at which experiments have yet been made. From the foregoing experiments it appears that at 63.7° carbonic acid gas, under a pressure of 223 atmospheres, is reduced to $\frac{1}{477}$th of its volume under one atmosphere, or less than one-half the volume it ought to occupy if it were a perfect gas, and contracted in conformity with Boyle's law. Even at 100° the contraction under the same pressure amounts to $\frac{1}{381}$st part of the whole. From these observations we may infer, by analogy, that the critical points of the greater number of the gases not hitherto liquefied, are probably far below the lowest temperature hitherto attained, and that they are not likely to be seen, either as liquids or solids, till much lower temperatures even than those produced by liquid nitrous oxide are reached.

Law of Gay-Lussac.—That the law of Gay-Lussac in the case of the so-called permanent gases, or in general terms of cases greatly above their critical points, holds good at least at ordinary pressures, within the limits of experimental error, is highly probable from the experiments of Regnault; but the results I have obtained with carbonic acid will show that this law, like that of Boyle, is true only in certain limiting conditions of gaseous matter, and that it wholly fails in others. It will be shown that not only does the coefficient of expansion change rapidly with the pressure, but that, *the pressure or volume remaining constant, the coefficient changes with the temperature.* The latter result was first obtained from a set of preliminary experiments in which the expansion of carbonic acid under a pressure of 17 atmospheres was observed at 4°, 20°, and 54°; and it has since been fully confirmed by a large number of experiments, made at different pressures and well-defined temperatures. These experiments were conducted by the two methods commonly known as the method of constant pressure and the method of constant volume. The two methods, except in the limiting conditions, do not give the same values

for the coefficient of expansion; but they agree in this respect, that at high pressures the value of that coefficient changes with the temperature. While I have confined this statement to the actual results of experiment, I have no doubt that future observations will discover, in the case, at least, of such gases as carbonic acid, a similar, but smaller, change in the value of the coefficient for heat at low pressures. The numerous experiments I have made on this subject will shortly be communicated in detail to the Society; and for the present I will only give the following results:—

Expansion of Heat of Carbonic Acid Gas under High Pressures.

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·05° and 22·26 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
22·26	0·03934	1·0000	6·05	(A)
22·26	0·05183	1·3175	63·79	(A)
22·26	0·05909	1·5020	100·10	(A)

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·62° and 31·06 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
31·06	0·02589	1·0000	6·62	(B)
31·06	0·03600	1·3905	63·83	(B)
31·06	0·04160	1·6068	100·64	(B)

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·01° and 40·06 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
40·06	0·01744	1·0000	6·01	(C)
40·06	0·02697	1·5464	63·64	(C)
40·06	0·03161	1·8123	100 60	(C)

Taking as unit 1 vol. of carbonic acid at 6·05° and 22·26 atmospheres, we obtain, from series A, the following values for the coefficient of heat for the different ranges of temperature:—

$$a = 0·005499 \text{ from } 6·05° \text{ to } 63·79°.$$
$$a = 0·005081 \text{ from } 63·79° \text{ to } 100·10°.$$

From series B, with the corresponding unit volume at 6·62° and 31·06 atmospheres, we find:—

$$a = 0\cdot006826 \text{ from } 6\cdot62° \text{ to } 63\cdot83°.$$
$$a = 0\cdot005876 \text{ from } 63\cdot83° \text{ to } 100\cdot64°.$$

And in like manner, from series C, with the unit volume at 6·01° and 40·06 atmospheres:—

$$a = 0\cdot009481 \text{ from } 6\cdot01° \text{ to } 63\cdot64°.$$
$$a = 0\cdot007194 \text{ from } 63\cdot64° \text{ to } 100\cdot60°.$$

The coefficient of carbonic acid under 1 atmosphere referred to a unit volume at 6° is—

$$a = 0\cdot003629.$$

From these experiments, it appears that the coefficient of expansion increases rapidly with the pressure. Between the temperatures of 6° and 64° it is once and a half as great under 22 atmospheres, and more than two and a half times as great under 40 atmospheres, as at the pressure of 1 atmosphere. Still more important is the change in the value of the coefficient at different parts of the thermometric scale, the pressure remaining the same. An inspection of the figures will also show that this change of value at different temperature increases with the pressure.

Another interesting question and one of great importance in reference to the laws of molecular action, is the relation between the elastic forces of a gas at different temperatures while the volume remains constant. The experiments which I have made in this part of the inquiry are only preliminary, and were performed, not with pure carbonic acid, but with a mixture of about 11 vols. of carbonic acid and 1 vol. of air. It will be convenient, for the sake of comparison, to calculate, as is usually done, the values of *a* from these experiments; but it must be remembered that *a* here represents no longer a coefficient of volume, but a coefficient of elastic force.

Elastic Force of a Mixture of 11 *vols.* CO_2 *and* 1 *vol. Air Heated under a constant volume to different temperatures.*

Vol. CO_2.	Temperature. Degrees.	Elastic Force. Atmospheres.	
366·1	13·70	22·90	(A)
366·2	40·63	25·74	
366·2	99·73	31·65	

256·8	13·70	31·18	(B)
256·8	40·66	35·44	
256·8	99·76	44·29	

From series A we deduce, for a unit at 13·70° and 22·90 atmospheres :—

$a = 0{\cdot}004604$ from 13·70° to 40·63°.
$a = 0{\cdot}004367$ from 40·63° to 99·73°.

And from series B :—

$a = 0{\cdot}005067$ from 13·70° to 40·66°.
$a = 0{\cdot}004804$ from 40·66° to 99·75°.

The coefficient at 13·70° and 1 atmosphere is—

$$a = 0{\cdot}003513.$$

It is clear that the changes in the value of a, calculated from the elastic forces under a constant volume, are in the same direction as those already deduced from the expansion of the gas under a constant pressure. The value of a increases with the pressure, and it is greater at lower than at higher temperatures. But a remarkable relation exists between the coefficients in the present case which does not exist between the coefficients obtained from the expansion of the gas. The values of a, deduced for the same range of temperature from the elastic forces at different pressures, are directly proportional to one another. We have, in short—

$$\frac{0{\cdot}004367}{0{\cdot}004604} = 0{\cdot}9485, \qquad \frac{0{\cdot}04804}{0{\cdot}05067} = 0{\cdot}9481.$$

How far this relation will be found to exist under other conditions of temperature and pressure will appear when experiments now in progress are brought to a conclusion.

Law of Dalton.—This law, as originally enunciated by its author, is, that the particles of one gas possess no repulsive or attractive power with regard to the particles of another. " Oxygen," he states, " azotic gas, hydrogenous gas, carbonic acid gas, aqueous vapor, and probably several other elastic fluids, may exist in company under any pressure and at any temperature without any regard to their specific gravities, and without any pressure upon one another." The experiments which I have made on mixtures of carbonic acid and nitrogen have occupied a larger portion of time than all I have yet referred to.

They have been carried to the great pressure of 283·9 atmospheres, as measured in glass tubes by a hydrogen manometer, at which pressure a mixture of 3 volumes of carbonic acid and 4 volumes of nitrogen was reduced at 7·6°, to $\frac{1}{378}$th of its volume without liquefaction of the carbonic acid. As this note has already extended to an unusual length, I will not now attempt to give an analysis of these experiments, but shall briefly state their general results. The most important of these results is *the lowering of the critical point by admixture with a non-condensable gas.* Thus, in the mixture mentioned above of carbonic acid and nitrogen, no liquid was formed at any pressure until the temperature was reduced below —20° C. Even the addition of only $\frac{1}{10}$th of its volume of air or nitrogen to carbonic acid gas will lower the critical point several degrees. Finally, these experiments leave no doubt that the law of Dalton entirely fails under high pressures, where one of the gases is at a temperature not greatly above its critical point. The anomalies observed in the tension of the vapor of water when alone and when mixed with air find their real explanation in the fact that the law of Dalton is only approximately true in the case of mixtures of air and aqueous vapor at the ordinary pressure and temperature of the atmosphere, and do not depend, as has been alleged, on any disturbing influence produced by a hygroscopic action of the sides of the containing vessel. The law of Dalton, in short, like the laws of Boyle and Gay-Lussac, only holds good in the case of gaseous bodies which are at feeble pressures and at temperatures greatly above their critical points. Under other conditions these laws are interfered with; and in certain conditions (such as some of those described in this note) the interfering causes become so powerful as practically to efface them.

The Use of Natural Gas Extending.—The highly satisfactory results obtained by the use of natural gas in puddling and heating furnaces at Erie, Leechburg, and other places in Pennsylvania, has induced a serious effort to bring this excellent fuel from the great gas well in Butler county, Pennsylvania, to the ironworks of Graff, Bennett & Co., and Spang, Chalfant & Co., in Pittsburgh.

It is proposed to use a pipe 6 inches in diameter, and 17 miles long; this will be carried in a trench 3 feet deep, and the work is under contract to be finished within a month.

DANA'S CORALS AND CORAL ISLANDS.*

The additions which Professor Dana has made to his work on Corals and Coral Islands,† in preparing his second edition for the English public, have made it the fullest and most advanced repertory of knowledge upon that interesting and still novel branch of natural history. Without sacrificing scientific precision he has succeeded in presenting the subject in a form intelligible to the ordinary reader, and in surrounding what might otherwise have been dry details and cumbrous technicalities with the charm with which a true lover as well as master of nature never fails to invest his theme. To the labors of those who have led the way, and to whom he fully acknowledges his obligations, he does justice in his prefatory observations. It will be seen at the same time that he is no mere compiler from the results of other men's research and observations, having himself had chief charge of the scientific corps under command of Admiral Wilkes in the United States Exploration of the Pacific from 1838 to 1842. The preliminary announcement of the great theory of coral-reef formation by Darwin came in happily to give a guiding light to the investigations awaiting the expedition. And of the fuller explanations since brought out by that great naturalist Professor Dana has not failed to avail himself, whilst adding new facts and scientific solutions in abundance from his own independent researches and from valuable works like those of Johnston, Hincks, and Gosse. The illustrations with which the book abounds are of great service, bringing vividly before the eye the variety and beauty of the manifold forms of coralline growth and structure, and imparting additional clearness to the writer's descriptions.

The popular mind has been all along under much misapprehension as to the nature and growth of corals, speculation or even superstition having largely held the place of facts. A special mystery has been supposed to attach to the domain and the functions of these minute "animalcules," as it was thought most fitting to designate the submarine workers. The use of such terms as polypary and polypidon sufficiently expresses the popular notion that each coral was the house or hive of a swarm of polyps, like the honeycomb of the bee, or the

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*From the *Saturday Review*, London, August 14th, 1875.

†*Corals and Coral Islands.* By James D. Dana, LL.D., Professor of Geology and Mineralogy in Yale College, etc. London: Sampson Low & Co. 1875.

hillock of a colony of ants. Even now that the extended taste for natural history, and the general familiarty with the contents of aquariums, have made the more intelligent part of the public familiar with the commoner forms of polyp growth, there is no little difficulty in realizing the process whereby, through the agency of soft molluscous tissues, which alone meet the eye, a substance of such hardness, and masses of such stupendous depth and volume, have been built up. There is however, after all, no greater mystery in a polyp forming structures of stone or carbonate of lime in continuous masses than in a quadruped forming its bones, or a mollusc or crustacean its shell. It is a simple case of secretion, and no more—a process among the first and most common of those which belong to living tissues: differing, indeed, in different organs in accordance with their end or function, yet essentially identical, whether in the animalcule or in man. It is most characteristic of the lowest kinds of life. Not that all polyps have equal powers of secretion, or that they can carry on their functions under all external conditions alike. But among them are found the greatest stone-makers. In their simplicity of structure they may be almost all stone, and still carry on the processes of nutrition and growth. Theirs has been the task throughout geological time of producing the material of limestones and marbles, consolidating under water the solid rocks which were one day to be upheaved and to form islands and continents for the abode and the study of man.

Mr. Dana's exhaustive treatment of his subject leads him to prepare the reader for the comprehension of the origin and distribution of reefs and islands by distinguishing between those organisms which have the secreting power and those which have not. Coral is never the handiwork of the many-armed polyps, these organs being no more concerned in the lime-secretion than our limbs or muscles are in bone-making; nor does coral partake of the nature of the cell into which the animal may withdraw itself like certain molluscs. Poets have drawn fancy pictures of the toil and skill put forth in the elaboration of coral masses, or of the shapeless worms which they conceive to writhe and shrink in the process; but nothing can well be further from the actual formation of the *carallum*, as the coral skeleton is called, which is secreted among the tissues of the sides and lower parts, not the stomach or the tentacles of the polyp. To the compound mass

produced by a process of budding analogous to that in vegetation, and consisting of several polyps with the corallum as their united secretion or base, the name of zoophyte has been generally attached, it being truly animal in nature, though plant-like in point of budding. As this term, however, conveys to many minds the idea of something between a plánt and an animal, which is false, Professor Dana would substitute for it *zöothome*, from ζωον, "animal," θωμος, "a heep," a term no less applicable to compound groups in other classes—*e.g.*, Rhizopods, Bryozoans, and Ascidians.

Besides polyps, which are the most important of the coral-reef builders, there are three other classes of organisms which secrete corallum. These are the Hydroids, related to the little hydras of fresh waters, forming the very common and often large corals called millepores; the Bryozoans, or lowest tribe of molluscs, deriving their name from the delicate moss-like corals they secrete, no longer prominent as builders, but in Palæozoic ages so abundant that some beds of limestone are half composed of them; and certain Algæ or seaweeds, barely distinguishable from true corals, save that they have neither cells nor pores. Each group is subjected to careful and minute classification by the author, the plentiful and beautifully defined woodcuts greatly aiding the mind of the reader. Following in general the limits of tribe and species assigned by Professor Verrill, he gives reasons for diverging from them in some cases. He unites, for instance, both the non-coral making and the coral-making species into one grand division, that of the Actionids, on the ground of the close resemblance of the polyps; and he also separates from the latter the Cyathophylloid corals, which differ from them in having the number of tentacles and interior septa multiples of four, a characteristic of the Alcyonoids, instead of six. In external aspect and in internal character all are essentially identical, the general type being that of the sea-anemone. In all alike the processes of life and death are for ever going on together *pari passu*, the coral secretions giving to the polyp a base whereon to mount upwards, lengthening itself at the top by the formation of fresh cells. It thus leaves the dead corallum behind as the upward growth proceeds, so that a polyp but the fourth of an inch long, or even shorter, is often found at the top of a stony stem many inches in height. In *Goniopora columna*, for example, the living part combines a vast number of living polyp-cells, growing and bud-

ding with rich exuberance, while below the old polyps have undergone the process of death, their cells retaining no distinction of surface, and blending into a uniform mass, disclosing, however, imbedded shells. Madrepores may branch into trees almost without limit, all below a slight distance from the summit being dead, this distance varying in different species; the dead coral below serving as an ever-rising basement of rock, often harder than ordinary limestone or marble, for the still expanding and rising zoothome. The large domes of Astræas, attaining, as they are said to do, a diameter of ten or fifteen feet, and alive over the whole surface, owing to a uniform and symmetrical mode of budding, are throughout the whole interior nothing but lifeless coral. Could the living mass which meets the eye be separated it would form a hemispherical shell of polyps, in most species not more than half an inch thick. There is thus no limit to the possible growth of corals. The rising column or dome may increase upwards indefinitely until it reaches the surface of the sea, when death ensues from exposure to the air, and not from any failure in the powers of growth. If the land supporting the coral domes or trees goes on gradually sinking, the upward increment may proceed till a thickness results of many thousand feet. Subsequent upheaval above the surface of the sea will result in mountain ranges of limestone or coral rag, which are known to have a thickness not much short of a mile.

The composition of coral forms an important part of Professor Dana's inquiry. Ordinary corals have a hardness a little above that of common limestone or marble, giving out a ringing sound when struck with a hammer. This may be owing, he considers, to the carbonate of lime being in the state of aragonite. It is a common mistake to suppose that coral, when first taken from its watery bed, is soft, and hardens through exposure. The live coral may feel somewhat slimy in the fingers, but if the animal matter be washed away it is found quite hard. Chemically the chief constitutent of all is carbonate of lime, in the proportion of 95 to 98 parts in 100, with $1\frac{1}{2}$ to 4 parts of organic matter, and some earthly ingredients, such as phosphate of lime, with a trace of silica, amounting usually to less than 1 per cent. Forchhammer found 2·1 per cent. of magnesia in *Corallium rubrum*, and 6·36 in *Isis hippuris*. The sources of these constituents are the sea water and the ordinary food of the polyps, the process of absorption, assimilation, and secretion going on in them as in all animal or-

ganisms. A zoophyte, be it kept in mind, is as much an animal as a cat or a dog is.

Since Mr. Darwin's luminous exposition of the origin and growth of coral reefs and atolls, nothing remained but to multiply illustrations of the working of this great primary law, besides collecting such facts as might futher define the limit or local conditions of its action. Professor Dana's wide range of observation gives to his book its special value in regard to the causes which influence the growth and distribution of corals. These causes are most directly traceable in relation to latitude, to depth, and to local influences. Whether or not the coral-making polyps are organically distinguishable from others, it is abundantly clear that a certain minimum of temperature is essential to the formation of coral. Coral-building is confined to waters which through even the coldest months never sink below 68° F. A pair of isothermal lines crossing the ocean where this is the winter temperature of the sea, one north and another south of the equator, each bending in its course toward or from the equator wherever the marine currents change its position, will include all the growing reefs of the world, and the included area of waters may properly be called the coral-reef seas. This isocryme, or cold water line, of 68° F., is far from coincident with latitude. The author's chart shows at a glance the extent to which observation has thus far found it to range. It extends through mid-ocean in both the Atlantic and Pacific basins near the parallel of 28°, but varies greatly from this in the vicinity of continents, and accordingly affects to a corresponding degree the geographical distribution of reefs. This is of course but a temporary extreme, the summer heats greatly raising the temperature. The mean for the year is about 73½° in the North Pacific and 70° in the South, the summer mean being as high at least as 78° and 74°. Over all this area coral-reefs grow luxuriantly, but in the greatest variety and richness where the waters are hottest. A torrid and a sub-torrid region, as drawn out by Professor Dana, will be found to correspond closely with a marked difference in coral-growth. Not only, however, are the reef-building species separable generically from those of colder seas, but there are specific differences by no means to be accounted for between corals of seas identical in temperature. Thus not a single West Indian species occurs on the Panama coast, although on the Aspinwall side there are found nearly all the reef-building species of

Florida, nor is any West Indian species known to be identical with any from the Pacific or Indian Ocean. While, therefore, temperature has much to do with the distribution of reefs in latitude, there are certain local peculiarities which are not thus to be accounted for.

Contrary to the notions of early navigators, who judged from finding coral-reefs at immense ocean depths, the growth of coral is now known to be limited to a very narrow depth of water. What their soundings brought up were specimens of deposits sunk long ago, and far below their living bed. The range within which the polyps live is nowhere found much to exceed twenty fathoms, whilst they die immediately on exposure at the surface. This may be taken as the limit of coral life. A further condition is the necessity of pure ocean water, mud or sediment being as fatal to the coral polyp as to the oyster. At the mouths of great rivers consequently they will be looked for in vain. A more recondite cause must be sought for the absence of corals in certain areas where there are no mud-banks, volcanic action being almost certainly in some way concerned. That the effect of volcanoes in raising the temperature of the waters, or chemically affecting them, had been underrated by Mr. Darwin, was an opinion put forth by Professor Dana in the earlier edition of his book. In reply to this the question has been asked by Mr. Darwin, by what means could the heat or poisonous exhalations from a volcano affect the whole circumference of a large island? We are surprised to find this point, on which we dwelt in noticing Mr. Darwin's recent new edition, left here without further proof or illustration. The most important accessions of new matter relate to the extent and depth of ocean subsidence, as shown by the able observations of General Nelson upon the Bahamas, and those of Mr. Matthew Jones upon the Bermuda group, with correlative proofs of the like geological changes over the wide area of the Pacific. A great secular movement of the earth's crust may be inferred from these considerations, or rather the one local movement may be taken to have balanced the other. A vast Southern area, equal to one-quarter of the earth's circumference, sinking to the extent of perhaps ten thousand feet, must have caused a revolution in which the whole sphere of the earth must have been concerned. It accompanied, we may well believe, the immense upward movement of the North American continent preparatory to or during the great Ice epoch. This range of elevation and depression

is not indeed great compared with the upheaval which the Rocky Mountains, the Andes, Alps, and Himalayas have each undergone since the close of the Cretaceous era or the early Tertiary. Even our own country shows signs of disturbance not far short of this, and boundless time must be allowed for the accumulation of the Pacific reefs and atolls, considering the depths to which the adjacent soundings bear witness. All seems to confirm the belief that the main continental outlines of land and water have remained the same throughout. Oceans have always been oceans. Yet from the configuration of the North American continent, combined with that of the adjacent reefs, it may be judged that the peninsula of Florida, Cuba, and the Bahamas were once part of a vast prolongation of the southeastern angle of the continent, a submerged ridge being traceable between Florida and Cuba. The lonely Bermuda atoll confirms by its position the same deduction. The submerged coral banks on either side show that it is not wholly alone, but forms a summit in a long range of heights. So in the Indian Ocean the oceanic area was correspondingly affected by the coral island subsidence. As the islands or high lands sank beneath the sea, the corals built up their encircling walls. If the rate of subsidence kept up at all a corresponding pace with the coral secretion, the resulting atoll ring rose up as a crown far above the sinking intermediate cone, standing up from the ocean floor a monument to mark the site of the buried islet. A rate of sinking exceeding five feet in a thousand years would, according to the estimate arrived at by the author, as well as by most competent calculators, have buried islands and reefs together in the ocean.

Coming nearer home, the most lively interest for us centres in the question, under what conditions of temperature and depth were built up the thick masses of coral which enter into the limestone system of the British Islands, not to speak of the extensive Continental range of dolomite or magnesian carbonate of lime into which coral structure has been shown by analysts largely to enter. Did the isocryme of 68° extend as far as our northern seas, some vast divergence or expansion of the equatorial current, misnamed the Gulf Stream, imparting the necessary heat to our sub-temperate seas? or did a hardier class of corals keep up life and work in these northern latitudes? Beyond doubt, a coral reef of the Astræ tribe, and wide madrepore deposits during part of the Oolitic era (middle Jurassic), bear witness

to the active presence thus far north of zoophytes, which are now only found at work in tropical or sub-tropical waters. Upon this suggestive and pregnant fact, Professor Dana touches sufficiently to prove that he estimates aright its weight, and the vast width of its bearing. We hope to see it pursued more fully, and studied with the same keenness of apprehension, and the same patient elaboration of truth which characterizes the work before us.

RULES FOR CALCULATING THE WEIGHT OF ONE FOOT IN LENGTH OF ROUND, SQUARE, OCTAGON, HEXAGON, AND FLAT STEEL.

By W. F. DURFEE, Engineer.

The following rules for computing the weight of a lineal foot of those sections of steel in common use, have, in the absence of tables, been found by the writer, very convenient and sufficiently accurate for most practical purposes.

Rule for Round Steel.—Square the numerator of the fractional expression of the diameter of the bar whose weight is required, and divide this square by the number in the following table placed opposite the denominator of the fractional expression taken, and the result is the weight in pounds of one foot in length. If the diameter is expressed in

64ths	of inches,	divide the	square	of the	numerator by	1536·
32ds	"	"	"	"	"	384·
16ths	"	"	"	"	"	96·
8ths	"	"	"	"	"	24·
4ths	"	"	"	"	"	6·
$\frac{1}{2}$	"	"	"	"	"	1·5

If the diameter is expressed in

Inches, divide the square by . . . 0·375

Example.—Required the weight of one foot in length of $\frac{7}{8}$ths round steel: $7 \times 7 = 49 \div 24 = 2{\cdot}0416$ lbs. per foot.

Rule for Square Steel.—Square the numerator of the fractional expression of the side of the bar whose weight is required, and divide this square by the number in the following table placed opposite the denominator of the fractional expression taken, and the result is the weight in pounds of a foot in length. If the side of square is expressed in

64ths of inches, divide square of numerator by		1152·
32ds	" " " "	288·
16ths	" " " "	72·
8ths	" " " "	18·
4ths	" " " "	4·5
$\frac{1}{2}$	" " " "	1·125

If the side of square is expressed in

Inches, divide square of side by . . 0·281

Example.—Required the weight of one foot in length of $1\frac{1}{4}$ inches square steel: $1\frac{1}{4} = \frac{5}{4}$. $5 \times 5 = 25 \div 4{\cdot}5 = 5{\cdot}5$ lbs. per foot.

Rule for Hexagon Steel.—Multiply the weight of round steel of the same nominal dimensions as that of the hexagon steel whose weight is required, by 1·1, and the result is the weight in pounds of one foot in length.

Rule for Octagon Steel.—Multiply the weight of round steel of the same nominal dimensions as that of the octagon steel whose weight is required, by 1·054, and the result is the weight in pounds of one foot in length.

Rule for Flat Steel.—Multiply together the numerators of the fractional expression of the width and thickness of the bar whose weight is required, taken in the same denomination of fraction, and divide the product by the number in the following table placed opposite the denominator of the fractional expression taken, and the result is the weight in pounds of one foot in length. If dimensions are taken in

64ths of inches, divide product of numerator by		1152·
32ds	" " " "	288·
16ths	" " " "	72·
8ths	" " " "	18·
4ths	" " " "	4·5
$\frac{1}{2}$	" " " "	1·125

If dimensions are expressed in

Inches, divide product by . . . 0·281

Example.—Required the weight of a lineal foot of $\frac{3}{4} \times 1\frac{3}{8}$ steel; $(\frac{3}{4} \times 1\frac{3}{8}) = (\frac{6}{8} \times \frac{11}{8})$, then, $6 \times 11 = 66 \div 18 = 3{\cdot}66$ lbs. per foot.

The foregoing rules give weights slightly in excess of those due to the dimensions of the bars taken, but, as in most cases, steel is found to exceed its nominal dimensions. The rules will be found to give results approximating very closely to the actual weights of the various sizes of steel in common use.

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EDITORIAL.

The Construction of Iron Vessels.—Some discussion has followed the announcement that the large steamers recently built for the Pacific Mail Steamship Company had developed such weakness as to require extensive reconstruction.

It is generally known to engineers, that similar occurrences have befallen many of the iron ships, both foreign and American, but advertisement of these, not being demanded for stock-jobbing purposes, has not generally ensued.

In fact, the public interest is not so very great. Not one voyage in five thousand terminates in "never heard from," nor does one in fifty of the shipwrecks, which are happily very few when compared with the number of safe voyages, allow the catastrophe of final breaking up to be attributed to original defect.

The real parties primarily involved are the insurance companies and the owners, and the insurance companies can and do submit to some loss. If there were no risk, no one would insure. It is better to pay losses on damage to cargo or vessel, and to permit compara-

tively unsafe vessels to run, than to throw the loss on owners until they should elevate the character of their vessel above insurance, or if insured, to enable them to cut down the premium to small percentage. Owners, on their side, look to the first outlay. Ships in Scotland, as well as in the United States, are built for the least money possible, and the least money means the least material. The insurance companies, by two codes, one English, "Lloyd's," and the other French, "le Bureau Veritas," have established the least dimensions of parts they will take their *chance* upon, and the builders are openly instigated by the owners to compete for how near those rules, not to say how much below them, he will work. Some specious reason, such as the extra strength of American iron (overlooking the equality of meanness), will be found for *coming very close* in thicknesses, besides taking every advantage of the exact specification. The lowest price will get the job, and both owner and insurance company (the builder, perhaps not altogether avoiding his share), will assume the risk. If no storms intervene, and good luck waits the craft, she will float a long existence with high reputation to all. There are vessels built on all hands for the best possible, but in Scotland, as well as here, not at the price. The best Scotch builders must have £30 to £32 10*s*. per ton, for outfitted steamers, and the Cunards' are said to have paid in excess of £32 10*s*., while ships have been built for £22 10*s*.

It may seem a very low standard for iron ship-building, that the willingness to provide cheap work should exist. But the popular idea of enterprise is found in undertaking as the lowest bidder, and the result has broken, one by one, the larger engine shops of the country on the wheel of competition. So far as vessels are concerned, it would be a consolation if the loss from departure from those rules of purchase which alone give right to excellence, to wit, paying for it, fall mainly on the owners or insurers, but, unfortunately, the life of our great workshops is involved in this abuse of the contract or competitive system.

The attempt to secure excellence by specification, or even supervision, is as futile as the attainment of high morality by the law and the constable.

Water Supply Commission.—We learn that the labors of this Commission are drawing to a close, and that their report to the Mayor and Councils of this city is to be presented at the close of the present month. [It will be recollected that the engineers comprising this

Commission were selected by the Mayor from a list furnished, by request of Councils, by the Franklin Institute, and that one of the nominees, Mr. Fairman Rodgers, of Philadelphia, having declined to serve, his place was filled by the appointment of Col. Julius W. Adams, Chief Engineer of the Brooklyn Water Works, all being afterward unanimously confirmed by Councils.]

The Commission consists of Mr. W. Milnor Roberts, of New York, Chairman, Hon. Wm. J. McAlpine, of Albany, Col. Julius W. Adams, of Brooklyn, and Messrs. Wm. E. Morris and S. W. Roberts, of Philadelphia, in conjunction with Dr. Wm. H. McFadden, Chief Engineer of the Water Department. These gentlemen, when not in the field engaged in examining the various works, sources of supply, routes for proposed conduits, canals, reservoirs, and pumping stations, etc., have held their sessions in one of the rooms of the Franklin Institute, which was placed at their disposal for that purpose.

As the report of these gentlemen is not yet written, and when ready will first go to the Mayor and Councils, previous to being given to the public, we are of course unprepared to say anything respecting its views and recommendations, whatever these may be. We know that the subject is one of great importance, in which all the citizens of Philadelphia are naturally specially interested. Our city is growing so rapidly, and so largely in the direction of manufactures of every description, that a pure and abundant supply for its present and future wants is obviously a prime necessity.

The whole subject of the present and future water supply of our city has, during many years, received so much intelligent attention, that in the nature of the case not much room has been left for originality at the present day, respecting the sources of supply and general methods of introducing water to this large and growing metropolis; but an ample field of investigation still remained open in regard to the comparative merits of different schemes, the selection of the best source or sources of supply, the proper mode of bringing the water to a convenient centre of distribution, of preserving its purity, and securing a satisfactory delivery to the consumers. It is reasonable to presume that a commission of disinterested experts, selected as these gentlemen were on account of their known experience and engineering judgment, would not only give to the study of the questions involved the benefit of their experience, but that they would be able to present their views in such shape as to entitle them to the most

careful consideration, not only of the Mayor and Councils, but of the citizens of Philadelphia generally.

It would indeed be remarkable, if Philadelphia, situated as she is between two large rivers of fresh water, should not have it in her power to secure for her future growth, great as that may and probably will be, an ample supply of pure water.

There need be no doubt on that score, yet it still remains an open question as to what may be the most advisable course for the city to pursue in connection with our present water supply system, its immediate requirements and its unavoidable future extension. The water supply demands of modern cities, from various causes, increase in a greater ratio than that of the mere augmentation of population; and although this may be somewhat changed hereafter by the introduction of satisfactory means of avoiding waste, yet it is probable that it may always be true, especially in manufacturing cities.

When the Croton Aqueduct to supply New York was constructed, about a third of a century ago, the quantity of water it could furnish was deemed to be sufficient for a population of nearly or quite two millions of persons; yet it is already inadequate, and the city is at this very time, devising means of increasing the supply, which at present is about one hundred and ten million gallons per day, with a population of a little over one million. This shows a much larger supply per capita than is usually considered necessary even in manufacturing cities. It would appear to betoken waste, or a large consumption by the use of fountains. The period is probably close at hand when the City of Philadelphia will contain a population of over a million, and in view of that fact, and of its continued rapid increase, both in the number of inhabitants and in the extent and variety of its manufactories, the water supply has become a question of paramount importance, and it should, and doubtless will, always command the most careful attention and consideration of the representatives and executive officers of our city.

Special provision having already been made by the Centennial Commission for an additional supply of water for the Centennial grounds and buildings, no fears need be apprehended on that score; and if the city authorities should be prompt in carrying out the recommendations of the Water Supply Commission, there should remain no reasonable ground of complaint during the Centennial year, concerning the quantity and quality of the water supply in Philadelphia.

Improvement of Hell Gate Channel, New York —The Government works at Hallett's Point have reached their last stage of progress, but it will be nine months or more before the great explosion will take place. The excavations were completed about two months ago. They undermine a surface of $2\frac{1}{4}$ acres, and extend in headings and galleries 315 feet from land. The headings are the straight cuttings radiating from the shaft: they are 10 in number at the shaft and 41 in number at the outer edge of the semicircle. The galleries, 10 in number, are arcs of circles connecting the headings. The cuttings of both kinds aggregate 7,542 feet in length; they are from 12 to 13 feet wide, and from 8 to 22 feet high. Over their lowest point they are 53 feet below water. They leave a roof of solid rock 10 feet thick between the mine and the water. Over the outer edge of the excavation the water of the river is 26 feet deep at low tide.

At the intersection of the headings and galleries, columns or piers are left standing, by which the roof is supported. These number 172. The work of the final demolition of the reef will consist in breaking up these piers and shattering the rocky roof. Preparations for this are now in progress. Holes are being bored by steam drills in the piers and roof, into which charges of nitro-glycerine will be put, and all will be exploded at the same instant. There will be from 10 to 15 two and three inch holes in each column; and in the roof there will be three-inch holes about five feet apart. The charges of nitro-glycerine will average from 8 to 10 pounds, and all will be connected by gas-pipe filled with the same explosive. The nitro-glycerine in the pipe being fired by a friction battery, the charges will be exploded by concussion. Experiments have been tried under the direction of Government officials in regard to this method of exploding the charges, and the officers in command have no doubts as to successful results. At Mountain View, New Jersey, 2,000 charges were fired in this manner, and it is said that it was shown that there is no limit to the number which may be exploded simultaneously.

The final boring is less than half completed, and will occupy from two to three months more. It will take two months longer to charge the holes with nitro-glycerine, and the officers will wait till warm weather before firing the mine. Nitro-glycerine freezes at about 40° and is then practically inexplosive and safe to handle. The charges will be put in place during the winter, and will thaw out during the early summer. Before electricity is applied the water will be let in.

This will act as "tamping" and cause the explosion to be more effective. It is claimed that if only half the charges take fire, the work will be thoroughly accomplished.

The time for making the final attempt has not yet been fixed upon, but it is probable, for reasons connected with the annual appropriations, it will be soon after the 30th of June of next year. The work has been in progress six years—since 1869—having been delayed (and prosecuted at much greater cost,) because of the inadequacy of the sums of money voted from time to time, to allow continued and vigorous prosecution.

A further improvement at Flood Rock has been in progress about three months, and a shaft has been sunk about 50 feet in the solid stone. The same system will be pursued here as at Hallett's Point; but the excavations will be much greater in extent, as the rock stretches out about 400 feet in two directions from the shaft. No estimate can be made of the time it will take to complete this work, as it depends chiefly on the appropriations made by Congress. The removal of the reef at Hallett's Point will greatly reduce the dangers of the Hell Gate passage, and be a permanent advantage to commerce even before the second enterprise is brought to a successful conclusion.—*From the N. Y. Tribune, Sept.* 5, 1875.

The American Association for the Advancement of Science, on Weights and Measures.—The special committee of this association, to which this subject was referred, report upon the steps taken the past year for the establishment and perpetuation of the basic units of the metric system, and the results of the conference of delegates from twenty-one nations. The United States was represented by Prof. Joseph Henry, of the Smithsonian Institute, and Julius G. Hilyard, of the Coast Survey (now President of the association). The original standard meter and kilogram were adopted, and steps taken for authentic reproduction of them for distribution, and for comparison with other standards of dimension or quantity. The report comments upon and lauds the co-operation of our executive government in this great effort for universal civilization, and asks from all scientific bodies an expression of opinion to urge upon Congress the monetary aid desirable to meet the national share of the expenses; estimating the same at $12,000 original appropriation, with about $1,000 per annum subsequently. The committee say: "It is to be considered, that this is not designed merely to advance the

interests of the metric system of weights and measures, or to serve as a means of promoting the extension of that system. The design is higher than that. To secure the universal adoption of the metric system, would be undoubtedly to confer an immense and incalculable benefit upon the human race ; but it would be a benefit felt mainly in the increased facilities which it would afford to commerce, and to exactness in matters that concern the practical life of humanity. On the other hand, to secure that severe accuracy in standards of measurement which transcends all the wants of ordinary business affairs, yet which, in the present advanced state of science, is the absolutely indispensable condition of higher progress, is an object of interest to the investigators of nature immensely superior to anything which contemplates only the increase of the wealth of nations. * * * "

A series of resolutions were offered by the committee, and were unanimously adopted by the association. Those of our readers who are interested especially in the metric system, will find this report in full in the proceedings of the association, which will shortly be published.

Franklin Institute.

Hall of the Institute, Sept. 15th 1875.

The stated meeting of the Institute was called to order at 8 o'clock P.M., Vice-President B. H. Moore in the chair. There were 278 members and a number of visitors present.

The minutes of the stated meeting for June were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that since their meeting in June there had been 26 persons elected members of the Institute, and the following donations made to the library:

Memoirs of the Geological Survey of India. Vol. X, Part 2, Vol. XI, Part 1.

Records of the Geological Survey of India, Vol. VII, Parts 1 to 4.

Memoirs of the Geological Survey of India (Palæontologia Indica) being figures and descriptions of the Organic Remains procured dur-

ing the progress of the Geological Survey of India. Vol. I, 1. From the Superintendent of the Geological Survey of India, Calcutta, India.

Circulars of Information of the Bureau of Education, Nos. 1 and 2. Washington, 1875. From the Bureau of Education.

Transactions of the American Philosophical Society for promoting useful knowledge. Philadelphia. Vol. XV. new series, part 2. From the Society.

Reports of Scientific Investigations in relation to Sugar and Hydrometers, made under the superintendence of Prof. A. D. Bache, by Prof. R. S. McCullough. Washington, 1848. From the Secretary of the Senate.

List of Elevations, principally in that portion of the United States west of the Mississippi River, by Henry Gannett, M.E. Washington. From the Department of the Interior.

Bulletin of the United States' Geological Survey of the Territories. No. 4, second series. Washington. From the Department of the Interior.

Paine's British Palladio, or the Builder's General Assistant, etc., etc., by Wm. and Jas. Paine. Philadelphia. From Mr. Wm. W. Jefferies,

Geological Survey of Pennsylvania, 1874. Special report on the Petroleum of Pennsylvania, its production, transportation, manufactures and statistics, by H. E. Wrigley, with maps, etc., by D. Jones Lucas, and also map and profile of a line of levels along Slippery Rock Creek. by J. B. Lesley. Harrisburg, 1875. From the Board of Commissioners,

Second Geological Survey of Pennsylvania, 1874. Preliminary report on the mineralogy of Pennsylvania, by F. A. Genth, with an appendix on the hydrocarbon compounds, by Samuel P. Sadtler. Harrisburg, 1875. From the Board of Commissioners,

Circular No. 8, War Department, Surgeon-General's Office, Washington, May 1st, 1875. A report on the hygiene of the United States' Army, with descriptions of military posts. Washington, 1875. From the Surgeon-General, U. S. A.

Annual Report of the Auditor General of the State of Pennsylvania, and of the tabulations and deductions from the reports of the railroad, canal, and telegraph companies, for the year 1874. Harrisburg, 1875. From Wm. McCandless, Secretary Internal Affairs.

Bulletin of the National Association of Wool Manufacturers, 1875. From the Association.

Official Reports of Various Departments in the Vienna Exposition, 1873. From the Ministry of Foreign Affairs.

Supplements (No. 4) to the Seventh Annual Report of the Department of Marine and Fisheries, being for the fiscal year ended 30th June, 1874.

Reports of the Meteorological, Magnetic and other Observatories of the Dominion of Canada, for the calendar year ended 31st December, 1874. Toronto, Canada. From G. T. Kingston, Sup. Meteorological Office.

Minutes of Proceedings of the Institution of Civil Engineers, with other selected and abstracted papers, vol. 40, Session 1874–5, Part 2, by Jas. Forrest, Asso. Inst., C. E. Secretary. London, 1875. From the Institution.

Abstracts and Results of Magnetical and Meteorological Observations at the Magnetical Observatory, Toronto, Canada, from 1841 to 1871, inclusive. From G. T. Kingston, M.A., Director Mag. Observ.

Notes on Building Construction, arranged to meet the requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington. Part 1, Stage or Elementary Course. London, 1875. From J. B. Lippincott & Co., Philadelphia.

By-Laws, Rules and Regulations, together with Reminiscences of the Carpenters' Hall, etc., etc. Philadelphia, 1873. From Carpenters' Co.

The American Ephemeris and Nautical Almanac, for the year 1878. From Prof. J. H. C. Coffin, U. S. N.

Report of the Board of Health of the City and Port of Philadelphia, to the Mayor, for the year 1874. From John E. Addicks.

Practical Guide to the Determination of Minerals by the Blowpipe, by Dr. C. W. C. Fuchs, edited by T. W. Danby, London. From the Author.

Hand-Book of Land and Marine Engines, by Stephen Roper. Philadelphia, 1875. From Claxton, Remsen & Haffelfinger, Publishers.

Practical Hints on Selection and Use of the Microscope, by John Phin. New York, 1875. From the Industrial Publication Co.

Principles of Metal Mining, by J. H. Collins. New York. From the Publishers.

General Index of the Official Gazette, and Monthly Volumes of Patents of the United States Patent Office, for 1874. Washington. 1875. From the Commissioner of Patents.

Sixth Annual Report of the Geological Survey of Indiana, made during the year 1874, by E. T. Cox, State Geologist, Indianapolis. Indiana, 1875. From E. T. Cox.

Instructions in the Use of Meteorological Instruments. Compiled by direction of the Meteorological Committee, by Robert H. Scott, M.A. London, 1875.

Quarterly Weather Report of the Meteorogical Office. Published by the authority of the Meteorological Committee. Part 4, October–December, 1873. London, 1875. From the Meteorological Committee.

Lessons on Hand-Railing, for Learners, by Robt. Riddell. Philadelphia, 1875. From the Author.

Also, that at their meeting, held on the 8th inst., the following preamble and resolution were adopted:

WHEREAS, We understand that measures are being taken for the establishment in Philadelphia of a Museum of Industrial Art, with facilities in connection therewith for a course of instruction in design for artisans, similar to those offered at the South Kensington Museum of London. Therefore,

Resolved, That the Board of Managers of the Franklin Institute learn of this movement with pleasure, and fully appreciating the benefit that will result to our manufacturers from it. This museum promises to furnish superior advantages for the prosecution of the work in which this Institute was a pioneer, and has labored for more than half a century, and it has our most cordial wishes for its success.

Dr. C. M. Cresson read a paper on the effect of magnetic and galvanic forces upon the strength and destruction of steel and iron structure.

Mr. Robert Briggs then presented a paper on pseudo perspective for use in mechanical illustration. The method described was isometric and gives a semblance of perspective, which for illustration of articles to be grouped, becomes more nearly correct, and is less objectionable to the eye, than when shown with different perspective planes. It had also the merit of ready production from working drawings by the engraver's draughtsman.

The Secretary presented his report on novelties in science and the mechanic arts, embracing Jas. Henderson's process of making wrought iron; Leonard Krewson's apparatus for stopping leaks in vessels; G. M. Burth's window sash fastener; Richard's fire escape; Crofutt's life protector for firemen, miners, etc.; a window blind fastener, invented by Jonathan Bell; a triple hose connection by R. Grimshaw; an improved hose coupling, by W. A. Caswell, of Providence, R. I.; a new form of link for chain cables, by C. A. Chamberlin; a conical propeller wheel, by E. C. Hubbard; an improved scale beam, by T. Tebow, and M. S. Orum's flexible mandril for bending metalic pipes.

Mr. J. W. Nystrom presented and explained a telescope for field in-

struments, the invention of himself and Mr. Young, and also an instrument to measure and determine the imperfection in object glasses.

The Secretary then projected on the screen some pictures showing the advanced state of the Centennial Buildings.

A letter was read from Sir Edward Thornton, British minister at Washington, in relation to the award of the Albert medal of the Society of Arts, London, and also a list of medals awarded from 1864 to 1874 inclusive.

On motion of Mr. Robert Briggs it was resolved that the communication of Sir Edward Thornton, relative to the Albert medal, be referred to a committee of three persons, to be appointed by the chair at his convenience, which committee are hereby instructed to acknowledge in behalf of the Institute, the communication, and are desired to report at the next meeting of the Institute what action will be necessary to present to the Society of Arts the names and testimonials of any persons entitled to the medal.

Mr. J. E. Mitchell asked to have again read the resolution of the Board of Managers in relation to an Industrial Art Museum, which was done, whereupon he offered the following, which was adopted:

WHEREAS, The establishment of a museum of science, art and manufactures receives the hearty approval of the Franklin Institute, and with a view to and in the carrying out the project, Therefore, be it

Resolved, that the chairman is hereby authorized and requested to appoint, at his leisure, a committee of five members of the Institute to confer with similar committees from other bodies, with a view to organizing an institution similar to the South Kensington Museum in London.

Dr. C. M. Cresson offered a resolution in reference to publishing an abstract of the report on steam boiler explosions, and the strength of materials, which on motion of Mr. Sellers was amended to read as follows, and then adopted:

Resolved, that the committee on publication be requested to republish, entire, the reports upon "Explosions of Steam Boilers" and "Strength of Materials" made to the Institute in 1835 and 1836.

Dr. C. M. Cresson offered the following, which was adopted:

Resolved, That the committee on Science and the Arts be requested to appoint sub-committees upon the strength of iron and steel, with directions to make such experimental trials as may be necessary to include materials such as are at present found in the market, and

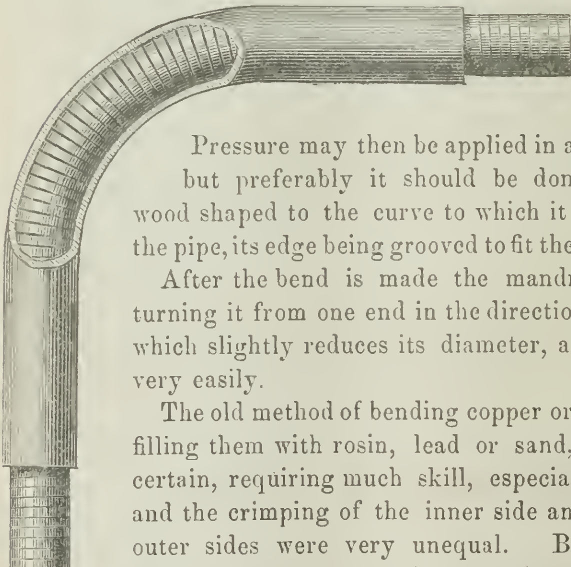
employed for the construction of boilers, bridges, and other structures of iron and steel, and that the sum of one thousand dollars be appropriated to the purpose of defraying the cost of the purchase and preparation of samples of iron and steel for the breaking machine. *Provided*, Such appropriation be deemed advisable by the Board of Managers.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary*.

Flexible Mandril for Bending Metal Pipes.—At the stated meeting in September, this instrument was presented and explained and practically tested by bending a 2-inch copper pipe.

The mandril consists of a coiled or spiral spring, made of square steel wire, and of such size as to be inserted freely into the pipe to be bent.



Pressure may then be applied in any convenient way, but preferably it should be done with a block of wood shaped to the curve to which it is desired to bend the pipe, its edge being grooved to fit the outside of the pipe.

After the bend is made the mandril is withdrawn by turning it from one end in the direction in which it wound, which slightly reduces its diameter, and it is *screwed* out very easily.

The old method of bending copper or brass pipes by first filling them with rosin, lead or sand, is tedious and uncertain, requiring much skill, especially for large pipes and the crimping of the inner side and stretching of the outer sides were very unequal. By this method the pipe was always considerably flattened and required hammering and filing into shape.

All these objections are obviated by the use of this instrument as it leaves the pipe so near perfectly round that the eye does not detect the variation. The surface is smooth so that there is no loss of metal (and consequently of strength) by filing into shape. Besides there is probably not one-twentieth of the time required in this as in the old process, and persons with much less skill can do the work with perfect success.

A number of specimens of pipes of different metals, copper, iron, tin, brass, and of sizes from ½-inch to 2-inch were exhibited, showing the general applicability of the mandril, but notably among them was a piece of butted zinc pipe, ¾-inch diameter, and bent to a curve of 1¼ inch radius.

Editorial Correspondence.

Editor Journal Franklin Institute.

SIR: In answer to your inquiry respecting the phrase "wane-edged," I can say that I never heard the expression from Philadelphia workmen, but I think your hint as to its meaning clearly points out its derivation, which is from the Anglo-Saxon *wana*, expressing deficiency or incompleteness. It means the *wanting* or imperfect edge or end of the timber. As thus derived, it might claim the slender Saxon a, and be written "wanedged." (See Chambers' Etymolog. Dict.)

Upon looking into "Webster," I find he gives the identical word as you have spelled it—notes it as "a deficiency in a board"—and marks it "Prov-English," which, I think, completes the answer.

Yours truly,

HECTOR ORR.

This reply gives the probable derivation, but does not substantiate itself. Older authorities and examples of use would be requisite.

The word is in common use with Philadelphia dealers and workers in wood.

Bibliographical Notices.

MINUTES OF PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS; *with selected and abstracted papers.* Vol. xli, Lesson 1874-75, Part III. Edited by JAMES FORREST, Assoc. Inst. C. E., Secretary.

Railway management and Dock construction, are the subjects of the papers, but the selected papers on many subjects, form most of the book. The great value of these papers, is that they are records of accomplishment, and not of proposition. Our serial engineering publications, lose most of their value as sources of information in the numerous schemes which find description in their columns, and it is very pleasant to turn from the weekly and monthly fictions of

engineering, to the real history of the art. For the serviceable use of the engineer, the Proceedings of the Institute of Civil Engineers is the most valuable of all books of reference.

MANUAL OF INTRODUCTORY CHEMICAL PRACTICE; *for the use of Students in Colleges and Normal and High Schools.* By GEORGE C. CALDWELL, S.B., Ph. D., etc., and ABRAM A. BRENEMAN, S.B., etc., in Cornell University. Ithica, N. Y., 1875. (Published by the authors.) This manual, like all other "royal roads" to learning, is evidently the work of conscientious teachers, who want to lighten the labors of students of chemistry, but who do not dread complicating exact science with a wearisome array of "nextlys." The method is in no way better than that of Fresenius, and the language at times is extremely crude and worrisome.

A conscientious study of Barker,* Regnault, or any of the recent compilations from the German will prove vastly more useful to beginners of chemistry than this manual, for it is nothing without them and a good deal of bother with them. In the glossary of "Appartus and Manipulation," the best part of the work exists, although even this is crude and at times inexact. The statements are evidently understood by the teachers but it would be difficult for a student to comprehend by his own, unaided efforts. R.

STORMS.—*Their Nature, Classification and Law, and the means of predicting them by their embodiments, "The Clouds."* By WILLIAM BLASIUS, formerly professor of the Natural Sciences in the Lyceum of Hanover. Philadelphia. (Porter & Coates). After the health of one's friend, the general subject of universal interest to civilized mankind is the weather, but while the pursuit of knowledge in direction of the laws of health may tend to produce advantageous results, the same pursuit (under difficulties) into the laws of weather offers little prospect of improvement, and becomes at best a kind of mental chess-playing. The study of phenomena will, however, be attractive to many minds, and the obvious and ever present one of *the weather* will find more investigation and more appreciation than many of the extensively examined subjects, and this book in its antagonism to some of the special theories, whereby other writers have tried to *simplify* to one rule, will lead towards more general knowledge of the diversity of conditions which exist. Strictly the work is neither elementary nor theoretical—perhaps it is not even logical—but it is a more succinct narration of facts and partial theories than is found elsewhere.

An exceedingly thin film of air covers the surface of our globe. Upon 200 millions of square miles is spread out a sheet of air 5 miles in thickness (the density of air being taken as upon the sur-

* "Barker's College Chemistry," New Haven, 1874.

face of the earth). The relative thickness of the atmosphere taken at this density to the extent of surface may be comprehended by saying it is that of a sheet of paper, such as the book on "Storms" is composed of, upon a sphere of 10 inches diameter, and the thickness taken at the usual supposition of 45 miles high of varying density is equivalent to 9 such sheets. This film is *boiled* by contact with the earth (generally) for 12 hours out of 24, (mainly upon a belt or zone which oscillates during the year about the tropics, but at the proper season in the temperate zones) and is condensed in the temperate and arctic zones. Tidal influences and those proceeding from the inequalities of surface of the earth also intervene.

The atmosphere is constituted of air and vapor of water; other gases or vapor, being too small in quantity to enter into consideration in influencing meteorologic phenomena.

This vapor of water would at any assumable sensible temperature and density, form that portion of a still atmosphere which its tension as steam of the same temperature would demand, but as the density of the atmosphere follows the elevation, and the sensible temperature falls away by well known laws, and the tension of steam falls off with sensible temperature much more rapidly than the rarefication of air, it follows that at some height not very elevated, an atmosphere saturated at the surface of the earth must be foggy with condensed vapor; and at some other height, yet more elevated, an atmosphere with a proportion of vapor less than saturation at the surface of the earth, would exhibit the same cloudiness.

Where clouds exist, they intercept most of the heat of the sun, and thus of themselves become a disturbing element in locating the points of ebullition from the earth's surface; and wherever evaporation is going on, the vapor of water and air form a mixture lighter than air alone, which increases the levity of the heated air.

The ebullitions are of every order—sweeping, horizontal currents, involving probably the whole depth of the atmosphere—overlaying sheets—rolls like shavings laid on the floor—spirals like the flow of water from a basin, (either on the surface of the earth, upwards, or in the upper atmosphere, downwards, transforming into sheets eventually)—and these several ebullitions *travel* over the surface of the earth in sweeps or coils of their own.

Currents of air in the form of sheets, (which are our usual winds) or in more restricted veins, acquire by impulse or by induction, high velocity, and when such velocities have been established, it must be recognized that an atom of air has as absolute momentum, as an atom of a cannon ball; but that while the cannon ball, (composed of dense atoms, compared with the medium in which it moves), from gravitation and the resistance of the medium, has a curved tragutory; the atom of air, *within the air itself*, is in equilibrium, and devoid of gravity, and its motion is a straight line. The direction of such currents, consequently, unless other influences are exerted, can be hori-

zontal only on one line of cross section, and thus every current from the line of its absolutely horizontal plane is tangential. If beyond this line, the current enters into a field or volume of still, or relatively still air of same density, it will rise from the surface of the earth, in place of following it, and at the distance of 200 miles from the normal line, attain an elevation of about 5 miles, and in the course of such elevation, a cloud will have been formed. In other words, that volume of air, in advance of the normal line of the current, which would be intercepted between the tangential plane and the earth surface, must be induced to move by some other force than the current itself, or else the current will rise above it.

This proposition of the atomic momentum of the fluid atom, having its direction or value unaffected by expansion or contraction, is the basis of the solution of the problem of the whirlwind or whirlpool, and has only been mentioned at this time, to elucidate how an extended cloud can be accounted for, without assuming counter currents or the intermingling of hot and cold strata, and to show how moderate velocity of winds may generate storms. The barometrical change produced by the supposed elevation of the undeviated current is inconsiderable.

Again, sheets or veins must manifestly have some point of maximum velocity, while with a fluid mass the stream must contract to attain such velocity, and expand in losing it. This contraction or expansion may be horizontal; sideways, on either side; or vertical, downwards or upwards. When the combination of contraction or expansion occasions a *thinning* of the sheet or vein, there is a downward shrinkage established, and the upper anhydrous air gives a clear sky; when the sheet or vein thickens, there is a piling up of the column of air, and *clouds are formed.*

Heat is not conducted between strata of air to any great extent, air or even vapor is too bad a conductor, but when two sheets, in diverse directions, one cold above, and one warm below, are sweeping by each other, the mingling is the rolling of currents between the two, and the cloud is the result of the upward roll.

The tornado is an induced upward current of the basin discharge order (following an unstable equilibrium of calm), and the same air which was breathed a few minutes earlier was that from which the hail-stones were derived. (Except that the hail-stones drop through an upward current of high velocity, they would acquire such force in falling as would produce the most disastrous effects.)

* * * * * * * * * * *

These, and similar truths, are the elements of Meteorology, and they are *not* set out in the book before us with that directness which could be desired by the student. It follows, that as a philosophical treatise, much is wanting, but as a statement of former theories and facts in ample and readable form, the work deserves many readers and high commendation.

Civil and Mechanical Engineering.

THE STEAM BOILER EXPLOSION AT THE KEYSTONE MILLS, TWENTY-FIFTH AND CALLOWHILL STREETS, PHILADELPHIA.

[It was for many years the usual practice of the JOURNAL to record the simple facts attending the explosions of steam boilers in Philadelphia, or its immediate vicinity. In accordance with this, the following communication is published. It is proposed to complete the record by similar descriptions of other explosions which have occurred within the past six or eight years.]

On Friday, May 8th, 1874, shortly after three P.M., an explosion of one of the six plain cylinder boilers, which furnished the steam-power for the Keystone Mills, took place. There were three pairs of boilers set in couples, each boiler being 30 feet long and 36 inches in diameter; the pairs having independent setting and all the appliances provided by law. Generally two pairs (or sets) were amply sufficient to give steam to drive the mills, but a few days prior to the explosion, some coal of bad quality was used, and it was found necessary to fire up the third set.

This third set had been standing idle for some time previously. In January, (1874), they had been put in condition for use in an emergency, having been then examined by the boiler inspector for an insurance company, and one of the two repaired at his suggestion.

On the afternoon of the explosion, the engineer noticed a leak in the repaired boiler, (which was the outside one of the third set), and immediately hauled the fire from this set, shut off the connections to the other two sets, and was in the act of attaching a water pipe to the blow off cock when the boiler exploded. The parting was at the third row of rivets, and the front head with two rings of the shell was projected nearly horizontally, about 150 feet, passing, in its course, through the board enclosure of a shed. The back end, with about 25 feet of the shell, was driven in the opposite direction (also horizontally) passing through a coal pile some eight feet in thickness, and stopping in a second heap of coal about 100 feet from the setting, the resistance of the coal retarding and finally arresting its flight.

The engineer, Hugh Sweeney, and a boy, Thos. Ivan Devor, were scalded and otherwise injured; both died the following day. There were narrow escapes, but no other injuries of person. The fracture followed the seam all around, partly in the line of rivet holes and partly on the line of caulking. At one place on the underside on the line of caulking, there was an old crack, with well coated surface, 17″ to 19″ long—a fracture evidently of long existence. The iron of the shell at the place of rupture had worn a little, perhaps a number of the gauge (that is, from No. 4, its original thickness, to No. 5.) The inspection had located the defect of the boiler at this seam, and there was a new patch along a part of it; the rent happening in the old sheet along the rivet holes, which joined on the new patch. As stated, 17″ to 19″ of old crack was disclosed. This weakness, together with the probable injury to the old sheet, from drifting out rivets and stretching the holes in putting in new ones, was sufficient to attribute *want of strength* as the cause of the disaster. The repairs had evidently been injudiciously made, and the boiler imperfectly examined on their supposed completion.

The experience of the writer has lead him to conclude that taking in consideration all the abuses of boilers in service, the average duration of boilers of good construction is about ten years. This boiler had been over twenty years in use, and its age should have called for close scrutiny when repairs were made.

WM. BARNET LEVAN,
Engineer.

STAND-PIPE FOR BLOOMINGTON, ILL.

By H. M. P. BIRKINBINE.

In constructing water-works for western cities, it is frequently impossible to have a reservoir, for want of the necessary elevated ground to place it upon. Many of the cities, have, therefore, been contented to adopt the direct supply plan; that is, pumping directly into the distributing mains, the plan adopted by Peter Morice, in the works built for supplying the city of London, at London Bridge, in 1582. The imperfections of such a system are apparent, the supply

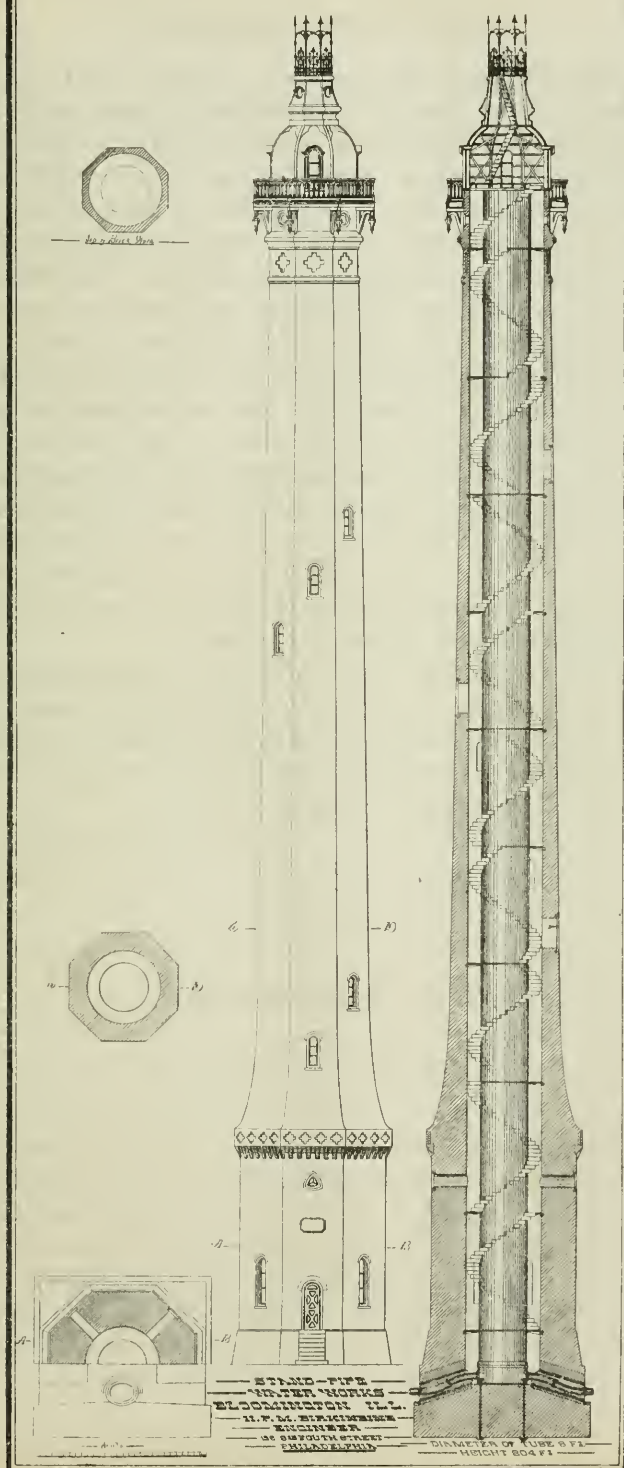


Photo-Lith. by J. CARBUTT, 624 N. 24th St., Phila.

depends entirely upon the integrity of the machinery; not a drop more can be procured than that which is pumped, and as it is pumped. The oscillations of demand must be answered directly by the operation of the pumps. The capacity of the pumping apparatus must, therefore, be equal to the maximum demand at any moment of the day or night. Expensive and complicated machinery is therefore necessary, little better than that constructed by Peter Morice, so long ago, who had two sets of *gang* pumps, four in each gang to a wheel. Very ingenious, but complicated arrangements have been devised for controlling the velocity of the modern direct supply pumps, by the pressure in the mains. The objection to this plan does not lay only in the complicated and unnecessarily large, expensive machinery, but also in the rapid wear and destruction of the apparatus. Another objection is the constant attention and watchfulness necessary, day and night, to keep up the supply of water, and the machinery in running order.

The stand-pipe is now becoming better understood and appreciated; it can scarcely be considered as a reservoir; still, it may contain a sufficient volume of water to allow for ordinary repairs, packing, stopping the pumps at night, etc.

The stand-pipe being built for Bloomington will contain 75,000 gallons. This would furnish a supply equal to a second-class steam fire engine, 400 gallons per minute, for one hour and a half, and still leave 100 feet of water in the tower, thus giving valuable protection against fire, should the pumping apparatus, for any cause, not be put into operation at the moment the fire was discovered. In the direct supply plan, not a drop of water could be procured until pumped, and sufficient pressure produced to project the water upon the fire. The stand-pipe has also a value in furnishing a place for the shocks incident to the working of pumps, opening and shutting of stops, and other like disturbing forces, to expend themselves.

The illustration represents an elevation, vertical section, and several cross-sections of the stand-pipe now being constructed for the city of Bloomington, Ill.

The pipe proper, or iron tube, is 200 feet high and 8 feet diameter, constructed of plate iron, secured to a cast iron base-plate. The plate iron varies in thickness from $\frac{5}{8}$ at the bottom to 3-16 at the top. The weight of the iron work will be 56 tons. The pipe is enclosed in brick masonry. The face bricks are white, with red brick trimmings

laid in black mortar. Fifteen hundred and thirty-nine cubic yards of brick and stone masonry will be required to enclose the pipe. An annular space of 27 inches to be left between the iron tube and the masonry, in which are suitable steps and platforms, leading to the top of the pipe. The tower is pierced with a sufficient number of windows to light the stairs. On top of the masonry is a dome 20 feet high, framed with wood, and covered with tin. Outside of this is a gallery supported upon brackets. The top of the dome has a lookout, protected by an ornamental railing, with guilded points.

This tower will present a striking appearance, and will be a landmark for a great distance around the city, and will give it a distinctive characteristic. The prospect from the summit will be grand and extensive, presenting an apportunity rarely had in that section, of looking down upon so wide an extent of country.

The contract price for building the entire structure, as represented in the illustration, is $26,700.

HOW THE METROPOLITAN RAILWAY IS WORKED.

HOWARD FLEMING.

The following description of the Metropolitan Railway (London) is extracted from the New York *Railroad Gazette* of August 28th. The success which has attended this means of communication in the large passenger traffic of a city is worthy of consideration in our important cities.

The Metropolitan Railway was commenced nearly twenty years ago, to give the Great Western Railway (having its terminus at Paddington) a city station about four miles to the east, at Farringdon Street. It has since been extended further eastward about a mile and a quarter to Bishopsgate, where it connects with the Great Eastern Railway, and from Paddington west by south to Kensington, where it connects with the Metropolitan District Railway (generally called the "District Railway,") also an underground line, which extends eastward, and of which more hereafter. These two railways form an irregular, almost complete ellipse, sixteen miles in length, of which each company possesses half.

The dimensions of tunnel are eighteen feet in height, and twenty-five feet in breadth, and the maximum distance of track from surface sixty feet. Accurate figures as to proportion of tunnel to open cut were not obtainable, but I should estimate it in the proportion of 10 to 1. The guage is 4 ft. $8\frac{1}{2}$ in. The sharpest curve on main line has a radius of 627 feet and on siding 396 feet. The maximum gradient is 1 in 70. The rails are steel, 24 feet long, and weigh 86 pounds to the yard. Their average life at railway stations, where the friction is very great, is two and a half years, and at other places, eight years. They are laid in cast-iron chairs weighing 39 pounds each, which are screwed to pine cross-ties 6 ft. by 12 in. by 12 in. placed 2 ft. 8 in. apart, and their average life has been seven years. The ballast used is gravel, which does not cover the cross-ties.

The weight of locomotives is $42\frac{1}{2}$ tons (of 2240 lbs.) The engines have eight wheels, a rigid wheel base of 9 feet, and a total wheel base of 19 feet. The diameter of drivers is 5 ft. 9 in.; weight on driving wheels, 32 tons. The cylinders are 17 in. by 24 in., and the boiler pressure is kept at 130 lbs. The fuel used is a medium hard, smokeless coal from South Wales, called Bwlffa coal, and the amount consumed is about 32 pounds per mile. Coke is also used. The speed maintained is 12 miles an hour, and the average mileage per engine is 130 miles per day.

The first-class cars are 40 feet long, 8 feet broad and 11 feet high, They are divided into six compartments, upholstered and decorated, each compartment containing seats for eight persons. They are mounted on two four-wheeled trucks, the diameter of wheels being 3 ft. 9 in. The car weighs, empty, 15 tons.

The second and third-class cars have the same dimensions and contain eight compartments, each seating ten persons. The only difference between the second and third class is that the former have their seats covered with leather, while the latter are simply painted boards; they weigh, empty, 14 tons.

The trains are generally made up of six cars, viz.: One first-class, two second-class, three third class. Sometimes there is an extra composite car of first and second-class compartments. Trains with six cars have a seating capacity for 448 persons, but at morning and evening, when the traffic is heaviest, it is no unusual sight to see people standing up between the seats, so that the number carried generally reaches 500.

Some smaller four-wheel cars of all classes have lately been put on the line, eight of which make a train.

Between Moorgate Street, the station first after Bishopsgate, and King's Cross Station, a distance of nearly two miles, four tracks are laid, so that the cars of other railway companies having their termini adjacent to the Metropolitan Railway within that distance (and with which they connect by short branch lines) may find a central city station without impeding the running of the regular Metropolitan trains. The railway companies that have made use of this great desideratum are the Midland and Great Northern railways, whose trains enter at King's Cross; the London, Chatham & Dover, whose trains enter between Farringdon Street and Aldersgate Street Stations; the Great Western Railway, whose trains enter at Paddington, and the London & Northwestern, whose trains enter at Uxbridge road (a station on the District Railway) and run to its terminus at the Mansion House. From Moorgate Street or Mansion House a passenger can take tickets to any stations on the main lines of the railways whose trains start from those two stations.

By changing cars a passenger can get on the system of the Southeastern and Southwestern, North London and West London Railways, so that the Metropolitan railways have acted the part of a mutual friend in bringing all the large railways centering in the city together, and have been a great boon to the traveling public.

In addition to these lines, which throw an immense amount of traffic over the Metropolitan, it has extensions or feeders of its own, such as the St. John's Wood Railway, $1\frac{3}{4}$ miles in length, and the Hammersmith & City Line, which last is an entirely open road about $2\frac{1}{2}$ miles long.

Summing up, we have the Metropolitan Railway, 8 miles in length; the District Railway 8 miles in length, and the St. John's Wood Railway, $1\frac{3}{4}$ miles in length, a total of $17\frac{3}{4}$ miles, which is mainly underground railway, and the ventilation of which has always been an uppermost consideration. Air shafts had been sunk where most practicable and required, and the stations were in open cuts, so that the circulation of air might be kept up. The engineer has recently placed deflectors in the air shafts, so that the passing train drawing its smoke after it would cause it to ascend and draw down after it the needed oxygen, but notwithstanding this, there is a sulphurous taste in the mouth for a short time after traveling on it.

Between Bishopsgate and Mansion House there are 22 stations. They are about half a mile apart from each other, and rarely exceed a mile. The round journey is accomplished in 55 minutes. The line is worked on the absolute block system of signals, so that no train can enter upon a section until it is telegraphed clear from the other end. Both points and signals are so connected at junctions or switches that derailments never take place, and accidents very seldom occur, and so far as I have been able to learn, there has been no loss of life from the company's negligence.

The first train arrives at Bishopsgate at 5.47 A. M., and the first train leaves at 5.50 A. M.; the last train is dispatched at 11.47 P. M., and the last train arrives at 12.35 A. M. Between those hours 195 trains are dispatched, and 196 trains received. The greatest interval between two trains is 15 minutes, and the least 2 minutes, the average interval being 5½ minutes. The stops at stations are very brief—not more than a minute—yet in that short space of time passengers alight and get in and the train proceeds. There are signs hung over the platform telling the passengers where to wait for the class he has taken ticket for; all is so systematically arranged that there is no rush to find your class.

The following figures show the number of passengers carried during a series of years on the Metropolitan Railway—the north half of the ellipse. The largest number carried on any one day was last Whitmonday, May 17, 1875, when 260,000 passengers were transported.

Year.	Number of passengers.	Year.	Number of passengers.
1863	9,455,175	1869	36,893,791
1864	11,721,889	1870	39,160,849
1865	15,763,907	1871	42,765,427
1866	21,273,104	1872	44,392,440
1867	23,405,282	1873	43,533,973
1868	27,708,011	1874	44,118,225

During the first six months of 1875 the Metropolitan Railway carried 23,543,567 passengers, and in commenting on the report the Chairman, Sir Edward W. Watkin (now in this country as agent of the Erie bondholders,) stated that in the last year they carried, on their eight miles of railway, 46 million passengers, whereas on the London & Northwestern, with 1600 miles, they carried only 44 millions; the Great Western, with 1532 miles, carried 34 millions; the Midland, with 1114 miles, 26 millions; the Great Eastern,

with 852 miles, carried 31 millions; the London & Southwestern, with 685 miles, 20 millions; the Great Northern, with 586 miles, 14 millions; the Brighton, with 345 miles, 24½ millions; the Southeastern, with 331 miles, 23 millions; the London, Chatham & Dover, with 157 miles, 20 millions; and the North London, with 12 miles, 19 millions.

In regard to rates of passage on the Metropolitan Railway, it would be incorrect to say that it is so much per mile; for instance, the fare from Bishopsgate to Mansion House, first class, is 24 cents, gold; second class, 18 cents, gold; third class, 12 cents, gold; but the rates to Victoria Station, between the two points, are the same. From Moorgate Street to Gower Street, the fare, third class, is 8 cents gold; distance, a little over two miles; while to Sloane-square Station, more than three times the distance, the fare is the same.

For annual tickets paid for at the time the rate of fare is about 50 per cent. less, and the holder can travel with one as many times a day between the two points for which it is issued as desired. Many people therefore avail themselves of these commutation tickets.

The cost of the Metropolitan Railway has been enormous, owing to its traversing valuable city property, the figure running up to over £800,000 per mile, which is equal to to $75, gold, per inch. The working expenses are 40 per cent. of the gross earnings. At the last semi-annual meeting a dividend at the rate of 3¾ per cent. on the ordinary stock was declared, an increase of ¾ per cent. over the dividend for previous half year, and the Chairman stated that he believed the line was capable, if the trains were longer and the stations were lengthened, of a development of at least 10 to 20 per cent. in the next two or three years.

As stated above, between King's Cross Station and Moorgate Street there are four pairs of rails, and at the latter station they open out into six pairs to accommodate the trains starting from and running through that station, viz: the Metropolitan use two pairs, and run 391 trains over them daily; the London, Chatham & Dover use one pair, and run 139 trains daily over it; the Midland use one pair, and run 113 trains over it daily; the Great Northern Railway use one pair, and run 85 trains over it daily; the Great Western use those belonging to the Metropolitan, and run 121 trains over them daily, and there is one spare line for use in case of emergency, Here is a total of 849 trains handled during the day, and on holidays and special occasions the number

generally reaches 1000. In addition to these there are the trains dispatched from the junctions, and the freight trains that are passing from one railway to another, making use of the Metropolitan as the connecting line. The men who can thus manage and efficiently operate a short line with such an immense traffic without hitch or accident are truly wonderful, and Mr. Schwabe, who investigated the working of the road in 1870, may well say: "This running is unique of its kind, and it is necessary to have seen it to admit its possibility."

The District Railway with their double track work 466 trains per day between 5.30 A. M., and 12.35 midnight, at an average interval of $2\frac{1}{2}$ minutes between each train. It is in many respects similar to the Metropolitan Railway, but all of its stations being in open cuts and the ventilation being superior, it is called the "Daylight Route."

An amalgamation of the District Railway with the Metropolitan has been proposed, but the shareholders of the latter at the present time are unwilling to carry it out.

Heating Feed-Water for Steam Boilers.—The editor of the *Railroad Gazette* has (in the issue of that paper of September 11th) an article on "Heaters for Locomotives," with a full demonstration that, supposing the temperature of feed-water be 40° Fah., the percentage of economy due to an increase of temperature of each 10° (over the 40°) derived from the heater is 0·85 of 1 per cent.

If the heater could raise the temperature of feed-water from 40° to 220°, the total gain would be only 15·25 per cent.

10 to 15 per cent. of the fuel, and work in handling it, and especially 10 to 15 per cent. increase of power may be too great a gain to be overlooked; but when the cost and maintenance of the heaters, the liability to get out of order, the impairment of the exhaust, etc., is considered, "it is evident that a feed-water heater, instead of being economical, may be the reverse." These deductions apply to all boilers and engines, as well as to locomotives although some of the conditions of application of heaters to stationary boilers are much more favorable for the use of heaters. It must be noticed, however, that under no circumstances can the percentage of advantage be greater numerically than is stated above.

GAS WORKS ENGINEERING.

By Robert Briggs, Civil Engineer.

The subjoined plans and specifications are examples of the more recent practice for telescopic holders and tanks constructed in the plainest and most economical manner compatible with good workmanship. The work was performed under contracts between the Citizen's Gas Light Company, of Buffalo, and the Southwark Foundry, of this city, for the holder, and between the same Gas Company and a building contractor of Buffalo for the tank. In the following number of the Journal will appear a description of an accident which ensued, and of the steps taken to repair the injury, with a discussion and report upon the subject.

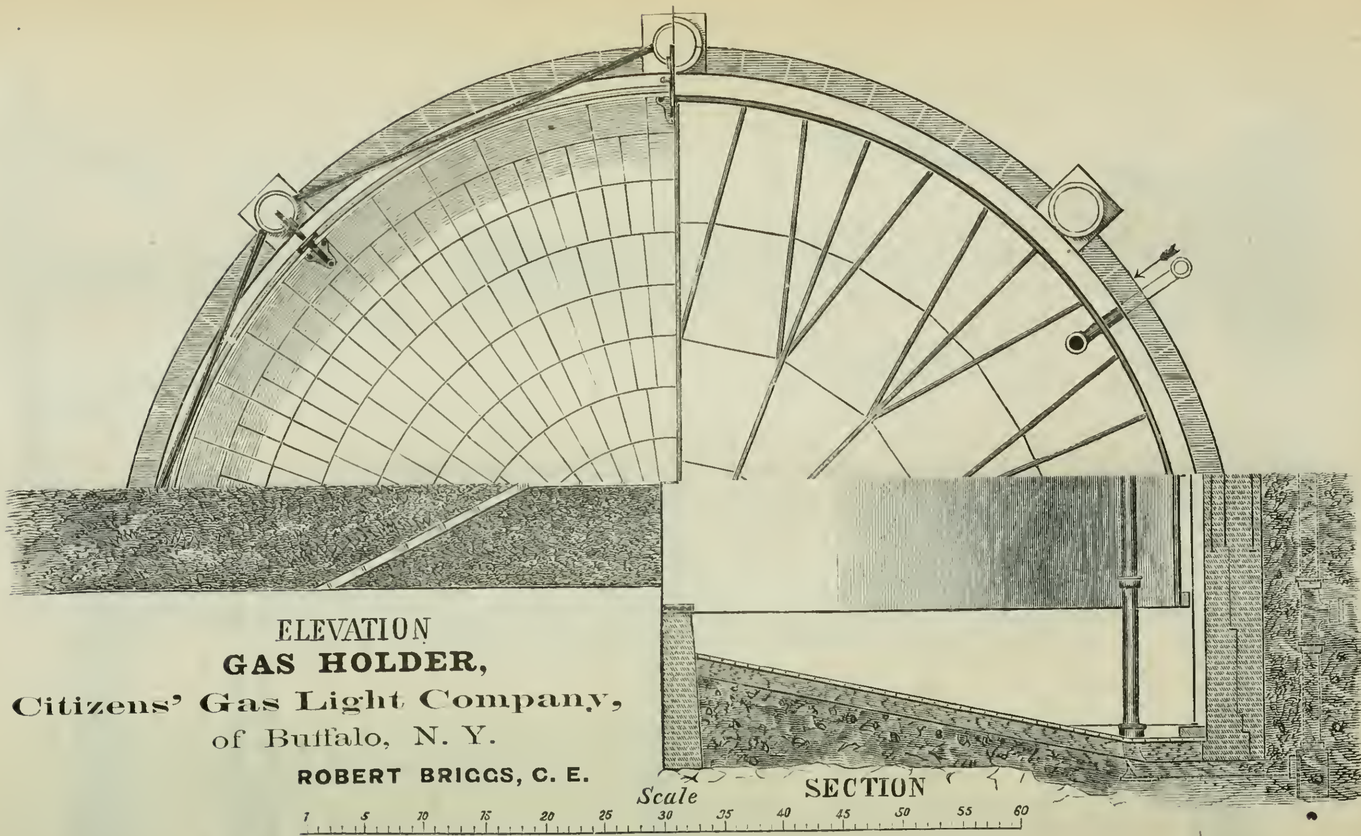
SPECIFICATION FOR A TELESCOPIC GAS HOLDER.

Citizens' Gas Light Co., Buffalo, N. Y.

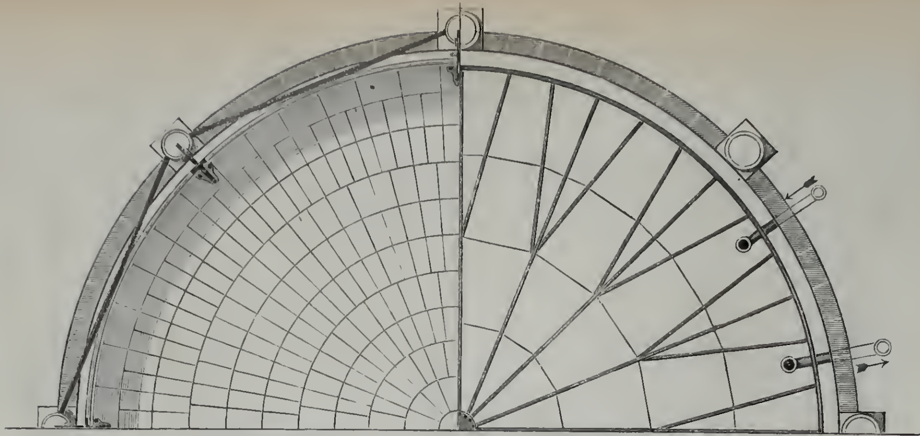
Inner Section,	Diameter, 88 feet 6 inches. Height, 22 " 0 "
Outer Section,	Diameter, 90 feet 0 inches. Height, 22 " 0 "
Cup,	Depth, 1 foot 3 inches. Width, 6 "

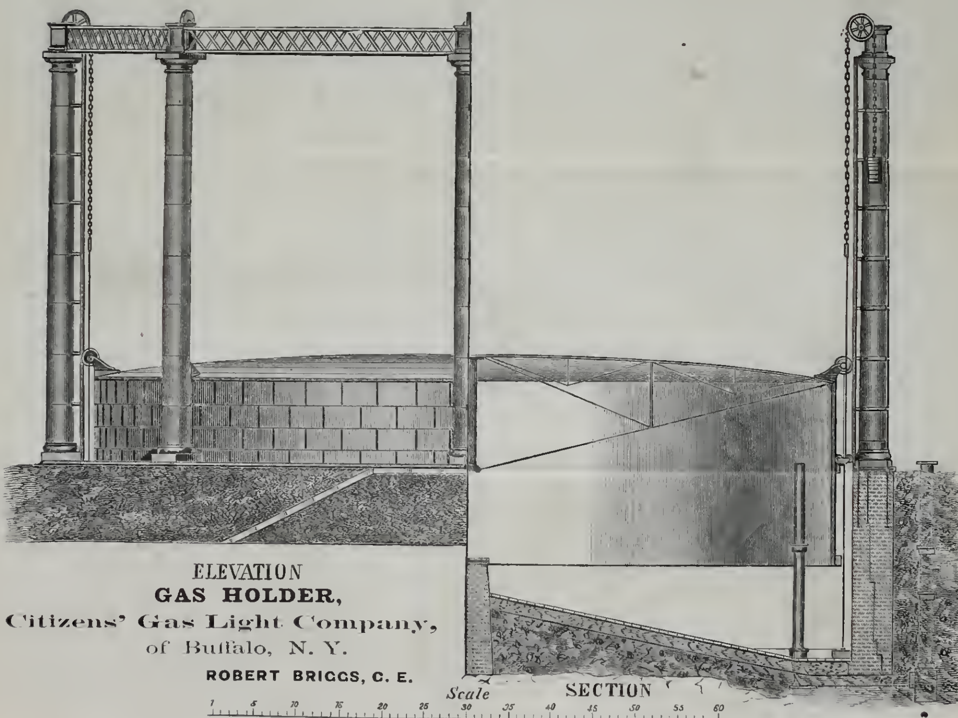
Working contents of Holder, 265,722 cubic feet.

This Holder will have a weight of $3\frac{5}{10}$ inches water pressure, when the Inner Section is down, which will be constant within $\frac{1}{10}$ inch, whilst the Inner Section lifts. The lifting of the Cup will increase the pressure $\frac{3}{10}$ inch, making $3\frac{8}{10}$ inches, and the Outer Section will be counter-balanced to $\frac{8}{10}$ inch pressure, making the maximum pressure $4\frac{6}{10}$ inches. The levity of the gas will very nearly balance the gain of weight of the sides as they lift from the water.



ELEVATION
GAS HOLDER,
Citizens' Gas Light Company,
of Buffalo, N. Y.
ROBERT BRIGGS, C. E.





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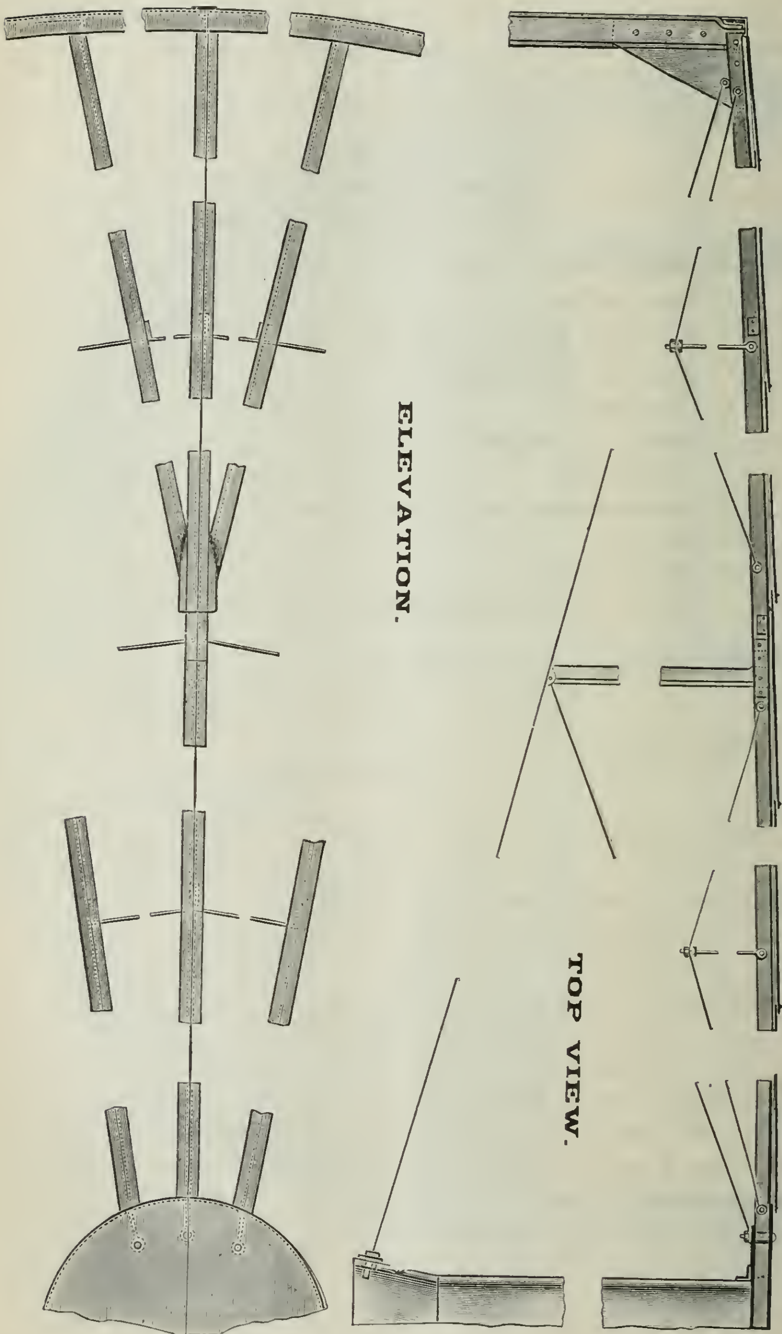

Framing of Crown of Gas Holder.

Crown to have the curvature of a portion of a sphere of three hundred and fifty feet radius, equal to 2 feet $9\frac{5}{8}$ inches rise.

FRAMING OF CROWN.

One Column King Post	Diameter, 1 foot 8 inches. Length, 14 feet 0 " Thick. of Sheets $\frac{5}{16}$ "
16 Queen Posts, tee iron, .	$3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{7}{16}''$
16 Main Rafters, " . .	$4'' \times 4'' \times \frac{7}{16}''$
32 Secondary Rafters, angle iron,	$3'' \times 3'' \times \frac{3}{8}''$
16 Main Tie Rods, round iron, .	$1\frac{1}{4}''$ diameter.
16 Secondary " " .	$1''$ "
32 Struts to Independent Trusses, round iron, ...	$\frac{7}{8}''$ "
32 Struts to Main Rafters, round iron,	$\frac{7}{8}''$ "
64 Tie Rods, " "	$\frac{3}{4}''$ "
80 Purlins, flat iron, ...	$2\frac{1}{2}'' \times \frac{3}{8}''$
Curb of Crown, angle iron, .	$4'' \times 4'' \times \frac{7}{16}''$

CROWN.

Centre Sheets, .	Diameter, 4 feet 0 inches. " 3 " 6 " Thicknesses, $\frac{1}{2}''$ $\frac{3}{8}''$
Curb Sheets, .	Width, 3 feet 3 inches. Thickness,* No. 9.

Inner row of Sheets next to Curb Sheets—
Length of Sheets, 4 feet 2 inches.
Thickness " No. 9.

Outer row of Sheets next to Centre—
Length of Sheets, 4 feet 2 inches.
Thickness " No. 9.

Remaining Sheets of Crown, No. 12.

16 Legs of Inner Section, Bulb iron, 45 lbs. per yard, and to have a backing plate of flat iron, $5'' \times \frac{1}{4}''$ on outside of section, countersunk riveted.

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* Refers to Birmingham Wire Gauge.

SHELL OF INNER SECTION.

(Upper) Curb Sheets,	Width, 2 feet 0 inches. Thickness, No. 9.
(Lower) Cup Sheets,	Width, 3 feet 0 inches. Thickness, No. 9.
Intermediate Sheets,	" No. 14.

CUPS, (both Inner and Outer Sections.)

Bottom, flanged channel iron, No. 58, $6'' \times 2\frac{1}{16}'' = 11$ lbs. per foot.

Sides, . . .	Width, 1 feet 3 inches. Thickness, No. 9.

Edge, bead iron, $2'' \times \frac{7}{8}''$.

16 Legs of Outer Section, flat iron, $2'' \times 1''$, and to have backing plate on outside of section, of flat iron, $5'' \times \frac{1}{4}''$.

SHELL OF OUTER SECTION.

(Upper) Cup Sheets,	Width, 3 feet 0 inches. Thickness, No. 9.
(Lower) Curb Sheets,	Width, 3 feet 0 inches. Thickness, No. 9.
Intermediate Sheets,	" No. 14.

Curb of Lower Section, angle iron, $4'' \times 4'' \times \frac{7}{16}''$.

All splices, gussets, thickening plates, where brackets are attached, &c., to be of suitable dimensions. Hand rail, of proper height, on top of Inner Section, and manholes on crown of same.

8 adjustable Carriages, base plates and guide wheels on top of Inner Section.

8 adjustable Carriages, with guide wheels and rollers for cup of Outer Section.

8 adjustable Carriages, with rollers for cup of Outer Section.

16 " " with rollers on curb of " "

16 " " with rollers on cup of Inner "

Two coats of metallic paint to be applied, one before shipment and one after erection; the latter coat on inside and outside of Holder.

Holder Frame.

8 Iron Columns, placed at equal distances around circle formed by the Tank, which shall be 91 feet 6 inches diameter.

Each Column to be constructed as follows:

The Base, Capital, and Entablature, to be of cast iron, of 1 inch average thickness.

The Base to be 2 feet $3\frac{1}{2}$ inches high, and 4 feet 8 inches $\times$ 4 feet 8 inches at foot, and to be provided with 4 holes, through which the foundation bolts will pass.

The Capital to be 2 feet 3 inches deep, and 4 feet 4 inches $\times$ 4 feet 4 inches at top.

The Entablature to be 3 feet 4 inches high, and securely bolted to capitals.

The Shaft at base to be 3 feet 4 inches diameter, and at top 2 feet 8 inches diameter, and 44 feet 0 inches high, and to consist of 8 sections of wrought iron. General thickness of iron in sections to be $\frac{5}{16}$ inches.

The Joints of the bases, capitals, and of each section of shafts, to planed, or turned off true and smooth, and the several parts secured together by $\frac{5}{8}$ inch bolts not less than 4 inches apart, or by $\frac{5}{8}$ inch rivets, countersunk flush on outside, $3\frac{1}{2}$ inches apart. [The vertical and horizontal joints in wrought iron sections to be made by plates $6'' \times \frac{5}{16}''$, with $\frac{5}{8}$ inch rivets, countersunk on outside, not less than $3\frac{1}{2}$ inches apart.]

Upon each column will be placed 7 Brackets to carry the guide rails, 5 feet 6 inches apart, bolted to the shaft of the column.

The Guide Rails of Railroad Iron, 20 pounds per foot, to be placed on each column, bolted to bases, capitals, and brackets, and to extend the entire height of column.

8 Wrought Iron Lattice Girders, 3 feet 0 inches high, connecting columns together at top, composed of two pieces of angle iron, 3 inches $\times$ 3 inches $\times$ $\frac{3}{8}$ inch at top and bottom, with flat iron, 3 inches $\times$ $\frac{1}{4}$ inches, crossed and riveted to angle iron, and at intersections.

Girders firmly bolted to capitals, and connected to entablature.

8 Chain Wheels, 3 feet 0 inches diameter, attached to entablature in such manner that the chain will pass through the centre of col-

umn, and in a perpendicular line with edge of cup of outer section of holder.

Counterbalance Weight, of 1200 pounds in each column, of convenient shape to move clear in the column.

8 Counterbalance Chains, $\frac{3}{4}$ inches diameter, connected by shackles to rod of weights and to crosshead.

8 Crossheads, with two rods, connecting chain to cup of outer section of holder, so constructed that the guide wheel of inner section will work free of chain.

A Wrought Iron Ladder on one of the columns, extending from top to bottom, of proper proportions.

16 Guide Plates, cast in pieces convenient lengths, and extending from top to bottom of Tank.

32 Foundation Bolts, 2 inches diameter, and 10 feet 0 inches long, to be built in Tank wall, and secured by cast iron washers, 12 inches $\times$ 12 inches $\times$ $1\frac{1}{2}$ inches at centre, and $\frac{3}{4}$ inches at edge.

Cast Iron Pipe, as per drawing, for 12 inch Inlet and 16 inch Outlet to Tank of Holder, with two drip boxes, 16 and 24 inches diameter, $\times$ 3 feet 0 inches, and $\times$ 3 feet 6 inches deep, with hand pump for same.

Two coats of metallic paint to be applied on all exposed surfaces of the Holder Frame, one before shipment and the other after erection; the inside of wrought iron columns to be painted.

The whole of the work specified to be delivered at Buffalo, and erected on the grounds of the Citizens' Gas Light Co., on the lot at the junction of Court and Georgia Streets, on or before the first day of December, 1874.

It is stipulated that the Tank shall be kept dry by the Gas Company, and that lumber for scaffolding shall be provided by them. The erection of and removal of which will be done by the builder, and the material shall be used without unnecessary waste, and, on completion of the Holder, be carefully piled upon the adjacent ground.

All carpenter work, masonry, excavation, and the placing of inlet and outlet pipes, and setting of foundation bolts and washers, and of tank guides in wall of tank, shall be done by the Gas Company.

All material to be of the best quality, and the work done in first-class manner, subject to the inspection, and to be completed to the satisfaction of the Engineer of the Gas Company.

SPECIFICATION OF TANK FOR GAS HOLDER.

CITIZENS' GAS LIGHT CO., Buffalo, N. Y.

PLAN OF LOCATION OF HOLDER

INSIDE DIMENSIONS, { 91 feet 6 inches diameter.
22 " 8 " depth.

The level of top surface of curb will be 0 feet 8 inches above the general level of the ground around the tank, or 5 feet 6 inches above general level of the side-walks on Court and Georgia Streets.

The side walls and piers for the columns will be constructed in brick; the bottom and wall footings in brick or concrete (or brick with concrete.) There will be stone anchor blocks, stone coping around wall, and stone cap for centre pier, in manner and of dimensions hereinafter specified :

EXCAVATIONS.

The Excavation must be 97 feet 6 inches in diameter, with 8 recesses 5 feet 0 inches in length by 1 foot 10 inches in width (measured outside of diameter of tank excavation) for the piers of column foundation.

The excavation must be 24 feet 4 inches in depth, measured from upper surface of curb coping, or as much deeper as necessary to obtain good foundation, and be brought to a uniform level. Except that, in case the excavation is in rock, indurated clay or earth, or in

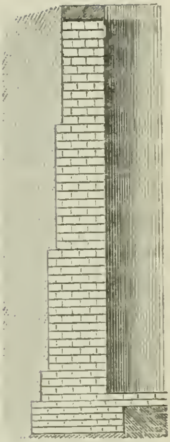
compact gravel, the recesses for column piers may then be made not deeper than one foot below column foundation bolts. And except where it is desirable to economize in removal of earth or stone from bottom of tank, when a cone with an inclined surface not more than one vertical in three horizontal may be left. The base of this cone must be at least 6 feet from inside face of the wall.

There is also to be excavated a recess and trench for the inlet and outlet pipes and drips, which are to be placed in position, as shown in accompanying plan, which excavation shall be of proper dimensions and depth, to allow the Gas Company to make joints. After the joints are made, the recess and trench must be filled and rammed with earth (or concrete, if necessary), as solid as the original ground. The sides of the excavation must be carefully shored to prevent caving; and in case of a slip, the entire mass of broken earth must be removed, and a new fill puddled and rammed in the back of wall.

If the bottom of the tank proves springy, there must be constructed a system of blind drains leading to a brick well, 3 feet 0 inches in diameter, and 1 foot 0 inches in depth below bottom of drains, which well shall be placed close to the walls of tank where most convenient to pump from. This well must have a cast iron plate (with poppet valve 8 inches in diameter) built into it one foot from top. The blind drains must be laid so that their covering bricks or stones will be under the concrete bed. There must be no attempt to keep the water out of the tank by the masonry of the bottom, but the springs must be allowed to discharge into the well, and through the valve into the tank; from which the water must be pumped by the contractor for the tank until the completion of the holder. In all cases, the bottom of the tank shall be made of a layer of concrete 15 inches in depth, with two courses of brick on flat on top of same.

The inlet and outlet pipes and drips must be placed by the contractor for tank. The joints will be made by the Gas Company at the proper time.

The tank guides and anchors will be built into the walls. The best method of holding the tank guides in position is to nail them by 12^{d} nails to six inch square wooden posts, placed inside the circle of the walls; which posts can be set plumb in the brickwork of wall footing at their bottom ends, and stayed to bank at their top ends. The posts can be removed after the walls are up, and the nails broken off.



The wall of Tank will be 4 bricks in thickness at the bottom or place of starting, which will be 20 inches below bottom of tank. [The footing will project ½ brick at back of wall, and 1½ bricks in front of wall.] The footing must be started at the level of bottom of blind drains, or of concrete, when there are no drains. The wall will contain 4 bricks for 2 feet 1 inches height. Then falling off to 3½ bricks in thickness for 7 feet 0 inches of height. Then falling off to...bricks in thickness for...feet...inches of height. Then falling off to...bricks in thickness for...feet...inches of height. Then falling off to 2½ bricks in thickness to curb.

The 8 column foundations will be in brick work, starting from bottom of excavation, as before described, and carried up plumb 5 feet 0 inches in length (along wall of tank), 4 feet 10 inches in width (measured from inside face of wall of tank), built up solid with and bonded into wall of tank. The foundation washers and bolts are to be set in position shown on drawing for these column foundations, as the work progresses.

Great care must be taken in setting out the circle of the tank, in the location of tank guides, and of the column foundations.

If the level of the ground around any part of the tank is such as to demand a bank of over two feet, and not over 5 feet) in height, the brick work must (against such higher bank) be increased in thickness a half brick by the omission of the uppermost reducing offset.

There will be laid in the course of mortar joint on the flat each ten courses of bricks; 3 or 4 strips of hoop iron 1¼ inches No. 20, 8 to 10 feet length, the ends overlapping about two feet, to make the bond of the wall. Every offset course and fifth course of bricks must be a heading course, and the heading courses must bond together across the wall.

The curb and column stone must be of N. R. flagging not less than 5 inches thick, or of Medina stone 8 inches thick. The curb must be flush with the inside of wall, and overhang the back 2 inches. The joints and edges of the curb must be carefully cut.

There are to be 16 anchor blocks of stone true and level on top, 24 inches long, 10 inches wide, 10 inches thick, placed at the foot of

each tank guide, 12 inches on one side of centre of same. These anchor blocks must be all at one level.

There is also to be provided a cap stone 3 feet 6 inches $\times$ 3 feet 6 inches on top by 10 inches thick for the centre pier.

The centre pier is to be built up to 13 feet 0 inches below top of curb, and left unfinished and uncapped until after the Holder is completed.

The mortar to be used for bricklaying, concrete, or cementing, must be made of one part of new hydraulic cement, of approved quality, and two parts of sharp sand, and must be used as fast as made; any set mortar must be rejected, and not tempered into new mortar.

The bricks used must all be hard burned and sound, and no bats must be received at the Tank. They must be properly wet down previous to laying, so as not to dry the water out of the mortar before it sets. Each brick must be laid and bedded in mortar, separately, and the end and side joint struck flush, before laying the next brick. (If the contractor will take the responsibility, he may lay the brick work by bedding each course in a cement mortar bed, and grout the side and end joints.) The brick work to be such as is usual in cistern or water tank work, of the best construction. Any brick work not meeting the approval of the engineer (or inspector for brick work, authorized by the Gas Company), must be at once removed, and reconstructed without cost to the Gas Company.

The Gas Company will hold the contractor responsible for the cost of reconstruction, and for damages which may follow, if the workmanship and material does not conform to this specification, whether noticed by the inspector or not; but will assume full responsibility for the tightness of the Tank, if the work is as specified.

Any surplus material from excavation must be deposited and leveled to the satisfaction of the engineer, within 60 feet of the Tank, and what is not thus used removed by the contractor.

Behind the walls of the tank there shall be filled in, rammed and puddled, suitable material to form a water-tight solid bank, and where the walls rise above the original surface, all loam or soil earth shall be removed for a space of 8 feet in width, and suitable puddle bank material substituted.

The bank shall be graded up to level of top of curb-stones, 6 feet in width, with a slope of two horizontal to one vertical to surface of

ground around. If the core of this bank be formed of clay, or material liable to be disturbed by frost, then there shall be eighteen inches of clean gravel spread on outside.

There shall be a cement plaster coat struck on inside of walls, before construction of Holder, and upon the surface of bottom, after construction of Holder.

If the Tank or excavation can be kept free from water, by the use of a hand pump, with two workmen employed in pumping, such pump and workmen shall be provided by and at the cost of the contractor. But should the quantity of water prove beyond the control of two men and a hand pump, the Gas Company shall provide and operate a steam pump of adequate size, with its boiler, and suction and discharge piping, without cost to the contractor.

It is stipulated, if the nature of the ground shall make it necessary to modify or change any of the requirements of this specification, such as sheet piling or coffer dam work in the excavation, building in trench to retain the banks, flooring under walls or bottom for sandy foundation, or piling for foundation, then such modification as may be authorized by the Company's engineer shall be made to meet the contingencies, and the extra cost of such changes shall be equitably paid by the Company.

It is presumed that the excavation will be in earth of some kind solely; but if rock is encountered, the quantity of rock to be removed from the inside of the tank shall be determined by the engineer of the Gas Company, and an extra price of...per cubic yard will be allowed the contractor for all rock removed. The stone after removal to belong to the Gas Company, if they desire to have it, but otherwise to be taken away by the contractor.

Additional Specifications of Gas Holder Tank.

There are to be built on the line of the lot on Court Street and on Georgia Street, two retaining walls in stone masonry, each about 32 feet in length (exclusive of wings at either end, which may be needed to hold the bank.)

These retaining walls, above level of sidewalk, are to be on the line of the lot and are to be carried up to the level of top of curb, (allowing a proper wash.)

Below level of sidewalk, these retaining walls are to have a footing upon the natural ground (under soil) and at least 3 feet under side-

walk level, which footing shall spread two inches in every foot of depth.

These retaining walls shall be built up solid against the brick walls of the tank, and the coping must be extended to cover both the tank wall and the retaining wall.

At the ends of the retaining walls there will be required wing walls from 18 inches to 2 feet in thickness with foundations at least 3 feet below sidewalk level, suitably coped.

All this stone masonry is to be rubble, mostly in two or three men stone and laid in gravel mortar. The retaining walls grouted in each foot of bedding. The coping to be same as specified for tank walls.

If any stone is taken from the tank, the contractor may use the same as far as it goes if it conforms to this specification.

The excavation for these walls will be made to such depth as may be directed by Engineer of Gas Company, and the materials removed or disposed of as provided herein for material taken from tank pit.

The retaining wall and wall of shed on east side of lot must be shored with spur shores or needles, and protected during the excavation and construction of the tank.

The water will be drawn from tank of Holder nearest the excavation as a safe-guard.

The contracts were as usual in such cases, and stipulated the terms of payment (that for the tank included the time of completion). As a part of the engineering of gas works it is not necessary to reproduce the forms of contract here.

(To be continued.)

Railway Safety and Practice.—At the recent meeting of the British Association, at Bristol, Mr. F. J. Bramwell delivered a well considered address on safety appliances to railways. Probably no person in England was better prepared to discuss the subject. But those observations which refer to tires are not at all applicable to American car wheels ; Bessemer boiler plates may be interesting, but at this time are not to be considered in our practice ; the block system appertains so little to our long line *time* running, as not to be a subject for our consideration. The locking of points has little practical value to us, and our heavy weight trains, with liability to line obstructions, lead to conclusions as to the value of brakes entirely at variance with the English estimation. With an evident completeness, from the English point of view, it is a curious comment that Mr. Bramwell's remarks have but little relevance to American railroads.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 177.]

Results with screw B.—This screw was two-bladed, and had the next greatest surface to screw C. Their surfaces compared as $5\frac{1}{2}$ to $8\frac{5}{8}$, and were of exactly the same kind.

With the blades of screw B held stationary in the vertical position, immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 828 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 197 pounds. Consequently, the screw, with its blades in the vertical position, increased the vessel's resistance $\left(\frac{197 \times 100}{631} =\right)$ 31·22 per centum; and decreased its speed ($\sqrt{631} : \sqrt{828} :: 7 : 8{\cdot}0186$; and $8{\cdot}0186 - 7{\cdot} =$) 1·0186 geographical miles per hour, or $\left(\frac{1{\cdot}0186 \times 100}{8{\cdot}0186} =\right)$ 12·73 per centum.

With the blades of screw B held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 976 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 345 pounds. Consequently, the screw, with its blades in the horizontal position, increased the vessel's resistance $\left(\frac{345 \times 100}{631} =\right)$ 54·68 per centum; and decreased its speed ($\sqrt{631} : \sqrt{976} :: 7 : 8{\cdot}7058$; and $8{\cdot}7058 - 7{\cdot} =$) 1·7058 geographical miles per hour, or $\left(\frac{1{\cdot}7058 \times 100}{8{\cdot}7058} =\right)$ 19·59 per centum.

From the above it appears that screw B, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{345}{197} =\right)$ 1·751 times the resistance it had when its blades were held in the vertical position, immediately behind the vessel's stern-post.

When screw B was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was consequently $\left(\frac{6086 - 5{\cdot}136 \times 921 \times 100}{6086} =\right)$ 22·28 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

With the vessel at the speed of 7 geographical miles per hour, and screw B revolving freely, the aggregate resistance of vessel and screw was 736 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 105 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{105 \times 100}{631} =\right)$ 16·64 per centum; and decreased its speed ($\sqrt{631} : \sqrt{736} :: 7 : 7{\cdot}5600$; and $7{\cdot}5600 - 7{\cdot} =$) 0·5600 geographical mile per hour, or $\left(\frac{0{\cdot}5600 \times 100}{7{\cdot}5600} =\right)$ 7·41 per centum.

From the foregoing it appears that the resistance due to screw B, when revolving freely, is 14·58 per centum of the resistance of the vessel, *per se*, less than when it is held stationary with its blades behind the stern-post in the vertical position; and 38·04 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel.

Results with screw A.—This screw was two-bladed, and had exactly double the surface of screw C, the surfaces of both being of exactly the same kind.

With the blades of screw A, held stationary in the vertical position immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 981 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 350 pounds. Consequently, the screw, with its blades in the vertical position, increased the vessel's resistance $\left(\frac{350 \times 100}{631} =\right)$ 55·47 per centum; and decreased its speed ($\sqrt{631} : \sqrt{981} :: 7 \cdot 8{\cdot}7281$; and $8{\cdot}7281 - 7{\cdot} =$) 1·7281 geographical miles per hour, or $\left(\frac{1{\cdot}7281 \times 100}{8{\cdot}7681} =\right)$ 19·80 per centum.

With the blades of screw A held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 1071 pounds; deducting from which the 631 pounds due to the resistance of the vessel there remain for the resistance of the screw, *per se*, 440 pounds. Consequently, the screw, with its blades in the horizontal position, increased the vessel's resistance $\left(\frac{440 \times 100}{631} =\right)$ 69·73 per centum; and decreased its speed ($\sqrt{631} : \sqrt{1071} :: 7 : 9{\cdot}1196$; and $9{\cdot}1196 - 7 =$) 2·1196 geographical miles per hour, or $\left(\frac{2{\cdot}1196 \times 100}{9{\cdot}1196} =\right)$ 23·24 per centum.

From the above it appears that screw A, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{440}{350} =\right)$ 1·257 times the resistance it had when its blades were held in the vertical position, immediately behind the vessel's stern post.

When screw A was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was consequently $\left(\frac{6086 - 5{\cdot}136 \times 921 \times 100}{6086} =\right)$ 22·28 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per

hour, the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position.

With the vessel at the speed of 7 geographical miles per hour, and screw A revolving freely, the aggregate resistance of vessel and screw was 765 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw *per se*, 134 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{134 \times 100}{631} =\right)$ 21·24 per centum; and decreased its speed ($\sqrt{631} : \sqrt{765} :: 7 : 7·7075$; and $7·7075 - 7· =$) 0·7075 geographical mile per hour, or $\left(\frac{0·7075 \times 100}{7·075} =\right)$ 9·18 per centum.

From the foregoing it appears that the resistance due to screw A, when revolving freely, is 34·23 per centum of the resistance of the vessel, *per se*, less than when it is held stationary with its blades behind the stern-post in the vertical position; and 48·49 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel.

Results with screw E.—This screw was four-bladed, with the blades equispaced around the axis. Each blade was exactly the same as one of the blades of screw C, so that screw E had the same kind of surface as screw C, and just double the quantity.

With screw E held stationary in such position that two of its blades were vertical and immediately behind the stern-post of the vessel, the other two being horizontal and square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 941 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, 310 pounds. Consequently, the screw, with its blades in the above position, increased the vessel's resistance $\left(\frac{310 \times 100}{631} =\right)$ 49·13 per centum; and decreased its speed ($\sqrt{631} - \sqrt{941} :: 7 : 8·5483$; and $8·5483 - 7 =$) 1·5483 geographical miles per hour, or $\left(\frac{1·5483 \times 100}{8·5483} =\right)$ 18·11 per centum.

With screw E held stationary in such position that all its blades stand at the angle of 45 degrees with the horizon, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 968 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 337 pounds. Consequently, the screw, with its blades in the above position, increased the vessel's resistance $\left(\frac{134 \times 100}{631} =\right)$ 22·24 per centum; and decreased its speed ($\sqrt{631} : \sqrt{968} : : 7 : 8·6696$; and $8·6696 - 7 =$) 1·6696 geographical miles per hour, or $\left(\frac{1·6696 \times 100}{8·6696} =\right)$ 19·26 per centum.

From the above it appears that screw E, when its blades were held at the angle of 45 degrees with the horizon, had $\left(\frac{337}{310} =\right)$ 1·087 times the resistance it had when two of its blades were held in the vertical position immediately behind the vessel's stern-post and the remaining two blades in the horizontal position square across the vessel.

When screw E was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was consequently $\left(\frac{6086 - \overline{5·136 \times 921} \times 100}{6086} =\right)$ 22·28 per centum less than the speed of the vessel; and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

With the vessel at the speed of 7 geographical miles per hour, and screw E revolving freely, the aggregate resistance of vessel and screw was 765 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 134 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{134 \times 100}{631} =\right)$ 21·24 per centum

and decreased its speed ($\sqrt{631} : \sqrt{765} :: 7 : 7\cdot7075$; and $7\cdot7075 - 7$ $=$) 0 7075 geographical mile per hour, or $\left(\frac{0\cdot7075 \times 100}{7\cdot7075} =\right)$ 9·18 per centum.

From the foregoing it appears that the resistance due to screw E, when revolving freely, is 27·89 per centum of the resistance of the vessel, *per se*, less than when it is held stationary with two of its blades in the vertical position behind the vessel's stern-post, and the remaining two in the horizontal position, square across the vessel; and 32·17 per centum less than when it is held stationary with its blades at the angle of 45 degrees with the horizon.

Results with screw F.—This screw (sometimes called the Mangin screw and sometimes the duplex screw) was four-bladed, and consisted of two pairs of blades placed immediately behind the other, so that when viewed in projection on a plane at right angles to axis, it appeared as a two-bladed screw with the blades directly opposite each other. Each blade was exactly the same as one of the blades of screw C, so that screw F had the same kind of surface as screw C, and just double the quantity.

With the blades of screw F held stationary in the vertical position, immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 721 pounds; deducting from which the 631 pounds due to the resistance of the vessel there remain for the resistance of the screw, *per se*, 90 pounds. Consequently, the screw, with its blades in the vertical position, increased the vessel's resistance $\left(\frac{90 \times 100}{631} =\right)$ 14·26 per centum, and decreased its speed ($\sqrt{631} : \sqrt{721} :: 7 : 7\cdot4826$; and $7\cdot4826 - 7 =$) 0·4826 geographical mile, or $\left(\frac{0\cdot4826 \times 100}{7\cdot4826} =\right)$ 6·45 per centum.

With the blades of screw F held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 851 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 220 pounds. Consequently, the screw, with its blades in the horizontal

position increases the vessel's resistance $\left(\frac{220 \times 100}{631} =\right)$ 34·86 per centum, and decreased its speed ($\sqrt{631} : \sqrt{851} :: 7 : 8{\cdot}1292$; and $8{\cdot}1292 - 7{\cdot} =$) 1·1292 geographical miles per hour, or $\left(\frac{1{\cdot}1292 \times 100}{8{\cdot}1292} =\right)$ 13·89 per centum.

From the above it appears that screw F, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{220}{90} =\right)$ 2·444 times the resistance it had when its blades were held in the vertical position, immediately behind the vessel's stern-post.

When screw F was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was consequently $\left(\frac{6086 - 5{\cdot}136 \times 921 \times 100}{6086} =\right)$ 22·28 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

With the vessel at the speed of 7 geographical miles per hour, and screw F revolving freely, the aggregate resistance of vessel and screw was 698 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 67 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{67 \times 100}{631} =\right)$ 10·62 per centum, and decreased its speed ($\sqrt{631} : \sqrt{698} :: 7 : 7{\cdot}3623$; and $7{\cdot}3623 - 7{\cdot} =$) 0·3623 geographical mile per hour, or $\left(\frac{0{\cdot}3623 \times 100}{7{\cdot}3623} =\right)$ 4·92 per centum.

From the foregoing it appears that the resistance due to screw F when revolving freely is 3·64 per centum of the resistance of the ves-

sel, *per se*, less than when it is held stationary with its blades behind the stern-post in the vertical position; and 24·24 per centum less than when it is held stationary with its blades in the horizontal position square across the vessel.

Results with screw II.—This screw has a large globular hub, and three blades cut to the pear-shape, which forms the Griffith screw. It has the same diameter as the previously-described screws, but its pitch is greater and expands gradually from the forward to the after edge of the blades.

With the blades of screw II held stationary in such position that one blade was vertical *below* the shaft and immediately behind the stern-post of the vessel, the remaining two blades being *above* the shaft and at angles of 60 degrees with the perpendicular, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 914 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 283 pounds. Consequently, the screw, with its blades in the above position, increased the vessel's resistance $\left(\frac{283 \times 100}{631} =\right)$ 44·85 per centum; and decreased its speed ($\sqrt{631} : \sqrt{914} :: 7 : 8·4247$; and $8·4247 - 7· =$) 1·4247 geographical miles, or $\left(\frac{1·4247 \times 100}{8·4247} =\right)$ 16·91 per centum.

With the blades of screw II held stationary in such position that one blade was vertical *above* the shaft and immediately behind the stern-post of the vessel, the remaining two blades being *below* the shaft and at angles of 60 degrees with the perpendicular, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 992 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 361 pounds. Consequently, the screw with its blades in the above position, increased the vessel's resistance $\left(\frac{361 \times 100}{631} =\right)$ 57·21 per centum; and decreased its speed ($\sqrt{631} : \sqrt{992} :: 7 : 8·7768$; and $8·7768 - 7· =$) 1·7768 geographical miles, or $\left(\frac{1·7768 \times 100}{8·7768} =\right)$ 20·24 per centum.

When the blades of screw H held stationary in such position that one blade was horizontal, square across the vessel on one side of the stern-post, the remaining two blades being on the opposite side of the stern-post and at angles of 30 degrees with the perpendicular, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 962 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 331 pounds. Consequently, the screw with its blades in the above position, increased the vessel's resistance $\left(\frac{331 \times 100}{631} =\right)$ 52·46 per centum; and decreased its speed ($\sqrt{631} : \sqrt{962} :: 7 : 8{\cdot}6431$; and $8{\cdot}6431 - 7. =$) 1·6431 geographical miles, or $\left(\frac{1{\cdot}6431 \times 100}{8{\cdot}6431} =\right)$ 19·09 per centum.

From the above it appears that screw H, when one of its blades was held stationary in the vertical position *above* the shaft immediately behind the stern-post of the vessel, had $\left(\frac{361}{283} =\right)$ 1·276 times the resistance it had when its blades were held in exactly the reverse position, that is to say, when one of its blades was vertical *below* the shaft immediately behind the stern-post. When one of the blades was held horizontly, square across the vessel on one side of the stern-post while the other two blades were on the opposite side at angles of 30 degrees from the perpendicular, the resistance of the screw (331 pounds) was but a little over the mean $\left(\frac{283 \times 361}{2} =\right)$ 322 pounds of its resistances with one blade vertical alternately above and below the shaft.

When screw H was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 665 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed (for mean pitch) of the screw was consequently $\left(\frac{6086 - 7 \times 665 \times 100}{6086} =\right)$ 23·51 per centem less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through

the water at the speed of 1·6459 geographical miles per hour. The revolutions of the screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

(To be continued.)

ATMOSPHERIC GAS ENGINES.

The explosive gas engine is a well-known machine, and although it met with little success in this country, in the form of engine constructed after M. Lenoir, it has maintained its place in Europe as a source of motive power since 1866. Another engine of a similar type to that of M. Lenoir has also met with a measure of favor in Europe, but neither of these two engines have been quite satisfactory in service.

From a paper prepared by Mr. Francis W. Crossley, and read before the Institute of Mechanical Engineers, at Manchester, England, it appears that some considerable improvement has been affected by Messrs. Otto & Layer. The main characteristic of the new engine is the *free piston.* The engine is really a gun, which stands vertically with open mouth, pointing upward ; the explosive compound of air and gas, is, however, not sufficient to drive the piston out of the cylinder, but only to within one or two inches of its mouth.

The piston rises freely and the motive power is derived from its weight (which is very small, however, for it is desired that the gases should expand to their utmost) and from the atmospheric pressure acting upon its upper surface, with the partial vacuum which follows the explosion, below it. In all the gas engines previously constructed, the force of the explosion has been the motive power. The effect of delivering this sudden blow against a piston, connected rigidly with a heavy fly-wheel, has been simply that instead of the heat, which is set at liberty by the union of the oxygen and hydrogen in the explosion, being converted into mechanical motion, it remains in the form of heat, and has to be got rid of by a very large external supply of cold water, lest it should destroy the surfaces of the cylinder and piston, and even lead—as it has often done—to the buckling of the piston-rod when it has grown red hot.

The blow given to the piston by the explosion has been received by the heavy mass of the necessarily heavy fly-wheel, which cannot rapidly yield to it : and just as when a cannon-ball strikes a massive target

which it cannot carry along with it, a flash of fire is the result in which the energy of the shot disappears, so in these engines heat instead of motion has been the result of the release of the stored energies of the gases.

The flame of carburetted hydrogen, when combustion is perfect, is intensely hot, and when repeated discharges take place—say 150 a minute—it is easy to see how much cold water must be circulated through the jacket of the cylinder to keep the temperature down to below that at which oil oxidizes, in order to prevent the destruction of the piston. It has been found possible, however, to keep the temperature sufficiently low even in these engines by supplying enough water, but it has taken a great deal, and where constant working is required; much has been added to the cost of running, and all the heat taken up by the water is carried off without doing work.

The difference in consumption of gas for the same power is found to be about as 1 to 6 in favor of the new engine, and as the cylinder in which this is burnt is also about 4 to 1 in volume, there is 24 times the space per unit of gas consumed relatively to the others. This leads to a less liability to clog from deposit, and to become equally dirty the engine would require 24 times as many hours' work.

The following abbreviated description will serve to give an understanding of mechanical contrivances adopted:

The piston-rod is a rack, and gears into a toothed wheel on the main shaft of the engine, which is mounted on the top of the cylinder. The length of the rack is about equal to twice the circumference of the wheel, so that the single-acting character of the engine is very different in its effect from what it would be in a steam-engine. The toothed wheel referred to is, however, not keyed fast upon the shaft, but is attached to it by a roller-pawl clutch, which permits the piston and rack to rise without moving the shaft at all, and connects them on the down stroke only. Thus the shock of the explosion is not sustained by the shaft, and the piston is able freely to move away from it, being arrested only by the resistance of the atmosphere at the upper end of the stroke.

The series of operations in each stroke, commencing with the piston at the bottom is:—First, the piston is lifted through a space of about 1-11th of the length of stroke, in order to draw in the charge of gas and air, and the power to affect this movement, is obtained from the momentum of the fly-wheel. The charge is then fired by contact with a gaslight, and the piston flies up freely to the top.

As it ascends, the plenum caused by the explosion is changed to a partial vacuum, which reaches to about 22 inches of mercury at the top of the stroke, and thus the motion of the piston is quickly reversed, and the down-stroke is performed under a pressure of about 11 pounds per inch derived from the atmosphere, and this driving power is communicated through the rack and wheel to the shaft. When the piston has reached within a short distance of the bottom, the vacuum, which has been gradually decreasing, is again exchanged for a plenum, and the weight and momentum of the piston and rack expel the burnt gases during these last few inches of the stroke.

The valves for admission of gas and of air have ports adjusted for proportioning the explosive mixture, and are worked by the obvious means of tappets or eccentrics, and the speed of the engine is regulated by a governor which acts upon the exhaust valve on the one hand and upon the supply (or explosion mixture) valve on the other.

But the most interesting question is the consideration of the engine from a purely scientific point of view. How many foot pounds are obtained on the brake per heat unit supplied by the fuel? Here the best steam-engines are surpassed by this gas engine. Were pure hydrogen the fuel instead of adulterated coal gas, no less than two-fifths of the theoretic efficiency of the fuel might be realized on the brake; coal gas, however, is less productive. Taking the proportion of gas to air for complete combustion as 1 volume of gas to $6\frac{1}{4}$ volumes of air, and the theoretic efficiency of the gas as equal to 24,113 heat units per pound weight consumed, one heat unit being equal to 772 foot pounds, and taking the density of the gas as 40 per cent. that of air, or 1 cubic foot of gas = 0·0305 pound in weight, then the heat units supplied to the engine per minute are 595,686, and the return for this on the brake is, say, 70,000 foot pounds, or 12 per cent. To compare this with the best steam engine, allowing for air-pumps and feed-pumps and friction, is it not even too much to say that 2 pounds of coal will give, under the most favorable conditions of a trial trip, 1-horse power per hour on the brake? Taking it at that figure, and taking the 1 pound of coal to supply 15,224 heat units, (an assumption of heat from coal which may be excessive, but which is coincident to the production of a horse-power from 2 lbs. of coal,) or 11,752,928 foot pounds, then $\frac{33,000 \times 60}{2} = 990,000$, or but $8\frac{1}{2}$ per cent. of the theoretic efficiency of the fuel, while the gas engine realizes 12 per cent., or nearly one and one-half times the amount.

QUADRUPLEX TELEGRAPHY.

By S. M. Plush.

There exists some doubt as to the origin of duplex telegraphy; some refer it to Dr. Gintl, in 1853.

It is certain, however, that experiments were made by the Electric Telegraph Company of England, in 1853; by Gintl, Siemens and Frischen, of Russia, about the same time; by De Sauty, in England, in 1855; and by the Magnetic Telegraph Company, between London and Birmingham, in 1856; but owing to various difficulties, not then to be overcome, the system was for the time abandoned, no advantageous results over the single method having been obtained.

It remained for J. B. Stearns, of Boston, in 1868, to make the duplex of practical importance, and he undoubtedly stands in the same relation to the duplex as Morse does to the single system.

While neither Morse nor Stearns perhaps were entitled to the credit of the discovery of the principles upon which their inventions were based, nor the fundamental laws by which they were controlled, still by a knowledge of these, and a proper combination and application of various mechanical appliances, some new, some old, instantaneous communication became a reality, whereas it was before a dream; and things that were seemingly impossible, were no longer so, as in double transmission on one wire. We cannot consistently withhold the credit from these men whose efforts have converted our scientific toys into instruments of usefulness, whereby our commerce and finance are enriched, and social pleasures enhanced *two*, yes, *fourfold.*

In 1872, the American Institute of New York, after a most careful and exhaustive examination, awarded the Great Medal of Honor to Joseph B. Stearns, for the invention of the Duplex Telegraph. Being the second of this class of medals issued since its foundation; the conditions upon which they were awarded being such as to exclude all inventions and improvements except those of paramount importance.

The Differential Duplex, as perfected by Stearns in 1868, consists of an improved transmitter or key, with double contact points, and more

recently, condensers, whereby the difficulties attending long circuits were entirely overcome, and the working capacity doubled. The helix is composed of two wires of equal lengths and resistances, the outer end of one and the inner end of the other being brought in direct contact with the key, one of the distant ends of these wires is connected to the earth through coils of the same resistance as the line. The transmitter is an ordinary Morse key, having two contacts, one with the battery when the lever is depressed, and the other with the earth when elevated, one contact invariably being made by spring connection *before* the other is broken. Thus the line is always to earth, either through the battery or direct. By depressing the key at one station, contact is made with the battery; the current dividing equally, passes through each coil of the relay at such station, in opposite directions. The magnetic power of each being equal, and of opposite polarity, produces no effect on the armature, while a current sent from the distant station passes through one coil only, and affects the armature corresponding to the signals sent. When both stations are sending, double the quantity of electricity which passes through the resistance coils, is passing through the line coil at either end. The cores of both relays therefore become magnetized by this difference, and signals are recorded simultaneously at both stations.

When this system of duplex was first tested on long lines, a very serious difficulty presented itself, caused by the discharge of return currents through the relay; being proportionate in volume to the static capacity of the line. *Electricity invariably follows the channel of least resistance to earth;* while in a long and well insulated conductor of large metal cross-section, electricity will flow through to the distant end, and to ground, so long as battery power is maintained; if ground contact be suddenly substituted for this, part of the charge left in the conductor at that instant, will return to the ground in preference to overcoming the resistance intervening between it and the distant ground.

The use of the condenser is to obviate this, by furnishing an additional static capacity, equal to that of the line; and by this means, circuits of several hundreds of miles can be successfully worked.

A condenser is an apparatus by means of which, a large quantity of electricity can be gathered on a small surface. Its form may be greatly varied, but the essential points consist of two good conducting surfaces, separated from each other by a non-conducting surface.

The charge depends on the size of the surfaces of the non-conductor placed between the condenser plates; on the tension of the electricity which furnishes the charge; on the distance between the metallic plates, and on their size. They are usually constructed of thin sheets of paper, saturated with paraffine, and covered on both sides within a short distance from the edge with tinfoil; they are then laid singly, one upon the other, like the pages of a book; the tinfoil plates being connected together in two series, upper and under. In this manner two separate rows of metallic plates are formed, separated by the paraffined paper, and presenting a large surface in a small space.

A rheostat is a combination of measured or known resistances, so arranged, that any desired amount can be put in circuit or removed at pleasure; the ends of the several resistances are connected to brass discs, which can be connected or disconnected by simply removing the metallic pins that connect these discs together. When the pins are in, an electric connection is formed from one disc to another; when they are out, this connection is broken, and the current obliged to pass through that portion of resistance corresponding to the discs. The resistance coils, as a rule, are wound with German silver wire; the specific resistance of which metal is but slightly affected by temperature.

Rheostats being composed of fine wire of a highly resisting material, have not the static or charge capacity of a long line: the metal of the one, weighing a few ounces only, that of the other, many tons of good conducting substance. No return charge, therefore, is felt from the rheostat. By connecting to the rheostat a condenser of equal static capacity to that of the line, a charge will be returned from it, simultaneously with that from the line, one balancing the other, and preventing any tendency to magnetize the cores of the relay. This system of duplex can be worked equally well with either pole of the battery to the line. When both stations use currents of the same polarity, they oppose each other midway, allowing the currents in the rheostat coils of the relays at the sending stations to influence the relays, the same as if both currents combined on the line.

The Bridge duplex (Stearns' more recent invention, on which the Quadruplex is based), is founded on the Wheatstone Bridge or balance principle. This method consists in the combination of the receiving instrument or relay with resistance coils, so that when a current is

transmitted from one station, it does not pass through the receiving instrument at that station, but directly to the line; the instrument at this station responding only to the currents sent from the distant station. Any kind of receiving instruments may be used in lieu of the relay.

When a current is divided between two circuits which are connected by a cross-wire or bridge, no current will pass through the bridge, provided the resistance of the opposite circuits on each side of the bridge are equal, or are in the same ratio to each other.

Fig. 1 will materially assist in comprehending the principle upon which this method is based. When the key (K) is closed, the current thus sent to the line will divide at H, one part flowing through the line, via A, the other through the resistance coils (R) to earth (g) via B, in the proportion of their respective conductivities. (Conductivity being the reciprocal of resistance.) Now, if the combined resistance of A and L be equal to that of B and R, no current will pass through the bridge wire, or if the resistance of the branch A, bears the same *proportion* to that of L, that B does to R, then no current will pass through the bridge. For example, suppose the resistance of A to be 500 ohms, L 2,000, B 250, and R 1,000, then no current would pass through the cross-wire, because the two circuits A and B are in the same proportion to each other, as L is to R. When the current reaches the distant station, it divides at F; one portion going to earth, via A and K, and the other to earth, via rheostat R, in the inverse ratio of their respective resistances. The instrument being placed between the points F G, is influenced by that portion, and thus records the signals. When, however, a current from the distant station is put on the line, the quantity of electricity on the line is doubled; but only the part supplied from either end, finds its dividing point at the distant point F, a portion passing through each bridge, thus effecting the relays, and recording the signals.

Figures 2 and 3 represent the rheostat and transmitting sounder in use in the bridge duplex. Fig. 2 contains the condenser plate, adjustable resistances and binding screws, for connecting the apparatus. The central disc is connected to the condenser, by binding screw C; the inner circle of discs is connected to earth, by binding screw E, and is attached to resistance coils of 1,000, 2,000, and 4,000 ohms each, corresponding with rheostat R, in Fig. 1. The outer circle of discs, corresponds with rheostats A and B, in Fig. 1,

FIG. 2

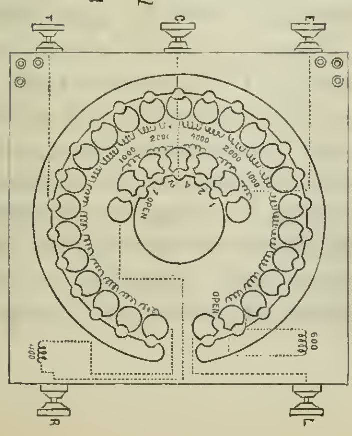


FIG. 1

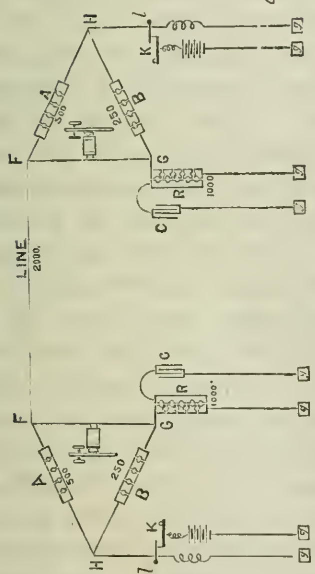


FIG. 3

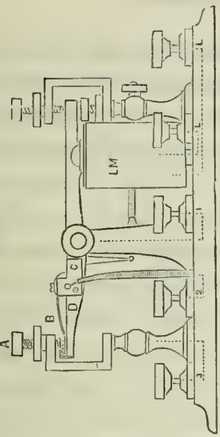
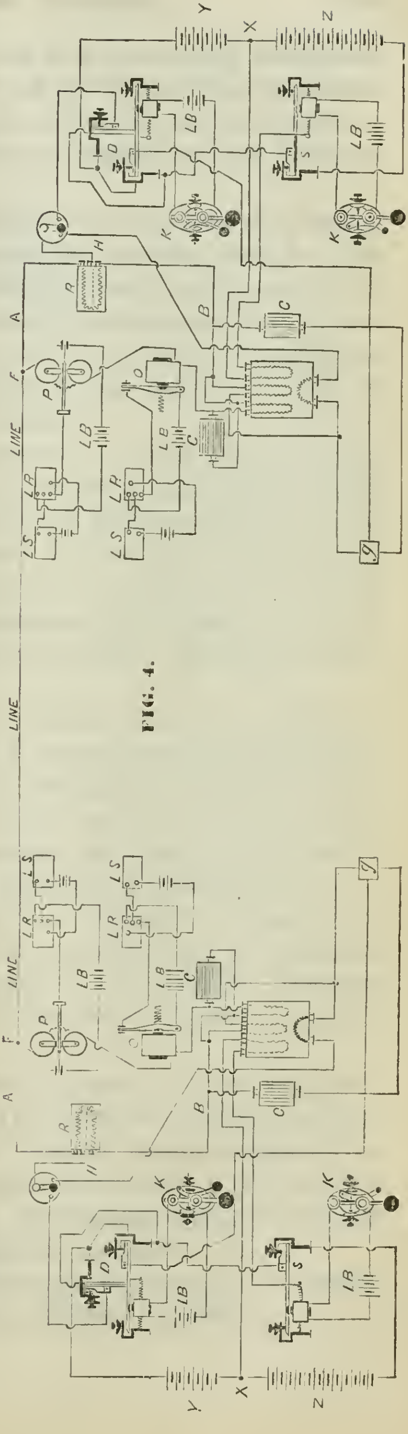


FIG. 4.



and is connected with resistance coils of 40 ohms each, terminating respectively with resistances of 400 and 600 ohms. The outer circular ring corresponds to the point H, in Fig. 1, and is attached to binding screw T, which is connected with binding screw 2, in Fig. 3, and corresponds with l, in Fig. 1.

The line wire, and one side of the relay, is connected with binding screw L, and the other side of the relay with binding screw R. The two sides of the bridge can be varied at pleasure, by the insertion of a plug at different points in the series of holes, between the circular ring, and outer circle of discs; and the third side of the bridge can be lengthened or shortened as desired, by the insertion of plugs in the holes between the inner circle of discs.

In Fig. 3, L and L are binding screws, for connection with a local battery and key, by which the transmitter is manipulated. Binding screw 1 is connected to the earth, and binding screw 3, with one pole of the main battery. Between 1 and the earth, and between 3 and the battery, are inserted small coils of resistance, for the purpose of maintaining a uniform resistance in both branches, and preventing the battery from being short circuited in changing from the back to the front contact.

Binding screw 2, is connected with binding screw T, of Figure 2. L M are the local magnet coils; A, a set screw and contact point connected with one pole of the main battery, the other pole of the battery being connected to earth. The earth is connected with the lever D; B is a contact spring, insulated at C, and connected as before described with the bridge ring terminal, by binding screw T.

When the key of the local circuit is depressed, the armature is drawn down at L M, which makes the contact between the spring and contact screw A complete, and breaks it with lever D. The operation being otherwise substantially the same as before described, need not be further explained.

The transmission of four messages over one wire at the same time; two in the one direction and two in the opposite, without confusion, or in any manner interfering one with the other, necessarily required for its development, a thorough understanding of the principles by which the duplex is governed. Electricians were then ready for the next great achievement in paradoxical inventions.

The Quadruplex, which as before stated, is founded on the bridge duplex, was invented by Prescott & Edison, in 1874.

[Other methods of the quadruplex have been brought to notice. That of M. Meyer, of the French Telegraph Administration, transmitting four messages over one wire in the same direction, and that of Dr. Nicholson, of Ohio, based on the differential principle. But as they have not yet proved of practical value, a description would be of slight interest here.]

According to their system, it is necessary at each station to have two transmitters and two receiving instruments, so arranged, that when one transmitter is closed, the corresponding receiving instrument only, at the other station, will respond. When the other transmitter is closed, *its* corresponding receiving instrument responds; and when both transmitters are closed at the same time, *both* receiving instruments respond; the receiving instruments at the sending station remaining unaffected by these operations, and ready to be influenced by similar manipulations at the other end. In order to accomplish this, two relays are placed in the bridge wire ; one a common relay of short cores, low resistance and counteracting spring, capable of being affected only by strong currents ; the other a Siemens' polarized relay of high resistance, and sensitive to feeble currents. The polarized relay is arranged with a closed stop in front, and an open stop back, in such a manner as to allow the tongue of the armature to make contact with one or the other, as the armature may be affected by the polarity of the current passing through the coils.

The common relay is provided with similar stops, having its closed stop on the spring side. Each relay is provided with two local batteries, one of which is connected through the relay points, and the coils of a local relay, which local relay is provided with contact points, so arranged as to close with the open circuit, or upward movement of the armature; this of course reverses the signals. The other local battery is connected through these points and the coils of the local sounder, which again reverses the signals, making them normal. (Fig. 4.)

One of the transmitters is a pole changer, having one spring connected to the line, and the other to the ground. The smaller portion of main battery is connected crosswise with the contacts of each spring, through the spring and lever of the single transmitter, which has an additional section of battery inserted between the lever and and its closing contact points. The movements of the double transmitter entirely determine the polarity of the current sent to line.

The other transmitter merely cuts in or out of circuit, an increased portion of battery—sufficient to close the common relay at the distant end.

By reference to Fig. 4, (which is an exact representation of the quadruplex, as in use by the Western Union Telegraph Company), it will be seen that the main battery is divided at X, (the division usually being as one to three); the smaller portion, Y, being connected to the double transmitter or pole changer, D; the larger portion, Z, to the single transmitter, S. Both transmitters are placed in a local circuit (L B) and manipulated by an ordinary Morse key (K). When both transmitters are open, the smaller portion of the battery will be presented to the line, through the double transmitter, (D), its currents will divide between the sides of the bridge at the point H, one portion passing through A, over the line, the other through B, via R, (rheostat) to ground. That portion passing over the line will divide at the distant point, F, one portion passing through A to key and earth, the other through the bridge wire and relays to earth. This current will influence the armature of the polarized relay (P) causing it to rest on the front or closed stop; but is not of sufficient strength to affect the common relay (O).

This same portion of battery is reversed by closing the double transmitter, which will reverse the movements of the polarized relay, causing its armature to rest on the back or open stop, and the local sounder, L S, responds. Still the common relay, O, is not visibly affected, though both currents have traversed its coils; but when the single transmitter, S, is closed, the full force of all the batteries is brought into action; that portion passing through the relays is now sufficiently powerful to attract the armature of the common relay, O, and the corresponding sounder speaks. The single transmitter cannot record a signal on the polarized relay when the double transmitter is open, because the current is of the wrong polarity—as before stated, the double transmitter determines the polarity of the current sent to line—if open, one pole of the battery is presented—if closed, the other, the single transmitter merely increases or diminishes the amount. The same results are obtained at the home end by similar manipulations at the other.

For reasons already explained, the bridge wire is provided with a condenser, C, charged by the relay currents. When the current is withdrawn from the relays, the condenser discharges before a re-

versed current reaches them, thereby prolonging the signals and maintaining a magnetic equilibrium of the cores.

The strength of current passing through the bridge relays, can be increased or lessened at pleasure. It not being necessary that both sides of the bridge shall be equal to each other, but that they should be in the same ratio, as explained when treating of the duplex.

The complexity of the apparatus, and the accurate adjustments necessary to utilize its full working capacity, require great skill and careful management. The officers of the Western Union Telegraph Company have proved themselves entirely *au fait*, and the quadruplex is now in daily successful use between the more important points of telegraphic communication in the United States. The distant points working direct with each other through intermediate repeaters.

For example, the circuit from New York to Chicago (nearly one thousand miles) is worked with repeaters at Buffalo. When desired, this circuit can be divided at Buffalo (by switches with which each complete set of instruments is provided) in such a manner as to allow New York to send to, and receive from Chicago, and Buffalo to send to, and receive from both Chicago and New York. Thus giving the capacity of one wire to, and from each of the points named.

When it is considered that by this system in addition to quadrupling the capacity of a wire, enabling communication direct with stations far distant—whose amount of business would not warrant the maintenance of a wire for that purpose alone, and allowing half the capacity of the wire to be used in sections if desired, for the benefit of intermediate stations, there is saved the investment for the cost of additional wires, and the liabilities to troubles, where many wires are crowded upon one line of poles, an indefinite idea may be formed of the value of this wonderful invention.

The perfection to which the telegraph has so rapidly approached, has virtually annihilated time and distance; is aiding the enforcement of the laws, and bringing the nations of the earth in more harmonious relationship—making all mankind friends, and the bond of union which civilization is each day riveting, a safeguard against future discord.

East, West, North and South—all are within the speedy reach of the lightning messenger, through whose invisible manœuvres, the untiring signals of the telegraph breathe the wishes of the world,

news of national or financial import, and tidings of joy or grief with unerring promptness.

The news of yesterday in the old world, becomes the theme of conversation to-day in the new; thus completing the triumph of science, and the testimony of success to energy and perseverance.

Photometry by Electricity.—Dr. Werber Siemens, in a paper read to the Verein für Gewerberfleiss, proposes a method of photometry measured by electrical currents.

The comparatively scarce, elementary substance *selenium* is quite nearly allied to sulphur, and, like sulphur, has amorphous forms, crystallizing on different systems at certain temperatures.

Amongst the properties of the amorphous crystals was one discovered by Lieut. Sales, that these crystals would conduct electricity better when illuminated than when in darkness.

This property was found to be permanent; that is, no permanent alteration of conductive power ensued from exposure to light, and the selenium returned to its original condition of conductivity upon removal of the ray. Heat, also, was effective in influencing the conducting power, and the effect of the heat decreased as the temperature increased, by some ratio, not stated.

Dr. Siemens has found a second amorphous condition for selenium crystals, formed at a somewhat higher temperature (we take these crystals to be opaque), in which the effect of heat on the conductivity is to increase the conductive power in place of decreasing it.

He encloses some coarsely crystallized selenium, of this second condition, between flat spirals of wire on two sides, and leaves of mica on the other sides, and by means of a battery or other source of electricity, has succeeded in transmitting sufficiently strong currents in the wire to indicate even weak intensities of light. Assuming the permanency of this property of selenium and the instantaneity of the recurrence of the change of conductivity, it would appear that we have at last an accurate register of comparative intensity, measurably, if not entirely devested from the effect of color, (which has impaired the visual methods,) and if the effect of heat can be diminished (or reduced to estimable comparative value); a perfect photometer.

This discovery is too important not to command attention, and the further development will be looked for with the greatest interest.—Extracted from the *Electrical News*, August 19th, 1875.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.†

[Continued from Vol. lxx. page 134.]

This report resulted from the minute investigations of MM. Péligot, Lamy, Troost, De Mondésir, and Le Blanc, who had been appointed as commissioners by the Prefect of the Seine in 1869. They undertook an examination of the process in the Place de l'Opera as well as in the laboratory. They burnt ordinary gas, boghead gas, and gas saturated according to different systems with liquid hydro-carbons, along with about half its volume of oxygen, and making use of various burners. They came to the conclusion that, for an equal intensity of light, the process of Tessié du Motay is almost always dearer—generally twice as dear—as the ordinary mode of lighting. In one case only, where the liquid hydrocarbons of the Boghead coal were used for carburetting by absorption in wicks, according to the plan of Levêque, over which the gas passed, it was found that the new process was twice as cheap as the ordinary method. This, moreover, applied only to the use of large burners, and the consequent production of great quantities of light. All the figures given by Tessié du Motay's Company, as to the cost of oxygen and the expense of carburetting, were taken for granted. In fact, however, it appeared that, in this experiment, 1 cubic meter of gas took up, not 50 grms. of liquid hydrocarbons, as the Company stated, but 266 grms., which rendered the economy of the process at any rate doubtful. As regards the strength of the light, the commissioners found it from three to seven times greater than that of common coal-gas. But Boghead gas in suitable burners can be made to yield a light three times

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† From the *Chemical News.*

stronger than that of coal-gas without the aid of pure oxygen. For most purposes, moreover a very great intensity of light is not desired as we see it reduced to 30 per cent. by means of glass shades and screens.

The conclusion of the commission, therefore, was to advise the municipality of Paris not to permit the laying down of mains for oxygen gas, but to leave it to the company to furnish oxygen and carburetted gas in portable gasometers to such persons as required an intense light.

The results obtained in Brussels were not more favorable. Lighting with oxygen was tried there last year for a short time in some coffee-houses and in the Passage St. Hubert, and given up on account of the above-mentioned disadvantages.* In Vienna, in April, 1874, the Westbahnhof was still lighted up with oxygen; but the system had made no further progress in that city, and the bluish moon-like light, in spite of its intensity and beauty, as represented above, was regarded as unsatisfactory.† The jury of the Vienna Exhibition examined the oxygen illumination at the Westbahnhof (Western Railway Terminus.) In the Exhibition itself the manufacture of oxygen was not represented.

Should further experience confirm these decisions, the manufacture of oxygen would be deprived of its present foundations. For it has been undertaken solely in the hope of the application of the oxygen to lighting purposes.

Many of the above-mentioned disadvantages, and especially the cost of the mains, are evaded in the arrangement which Phillips‡ proposes for oxygen illumination. This depends on lamps (manufactured by Berghausen, of Cologne), fed from an oil-cistern with very heavy tar-oil, rich in naphthalin, whilst oxygen is introduced into the centre of the wick. Whether great cities will be induced to give up the advantages of gas-lighting in favor of this arrangement, and whether it is practicable on the large scale, must be considered very doubtful.

The more we must hope that the manufacture of oxygen may be saved by the metallurgical demand. In medicine it has not found

* Letters from M. Melsens, Professor of Chemistry in Brussels, to Professor A. W. Hofmann, April 14th, 1874.

† Verbal communications from H. Hlasiwetz, Professor of Chemistry at the Polytechnicum in Vienna.

‡ Phillips, "Der Sauerstoff," Berlin, 1871, p. 46.

any general application. According to Pereira,* in spite of certain modern eulogies of the healing power of oxygen, there is, in the opinion of competent judges,† little to be said on the subject. We quote the passage :—

"Soon after the discovery of oxygen gas, a strong feeling arose in favor of its medicinal applications. Various diseases, *e. g.*, scurvy, were ascribed to a deficiency of it in the system, and it was accordingly employed in many cases, and, as was at first declared, with brilliant results. In England, it was tried by Beddoes and Hill.‡ The latter declares that he found it useful in asthma, weakness, ulcers, gangrene, white swellings, and scrofulous affections of the bones. These views have been again abandoned, both on chemical and physiological grounds. In asphyxia, from want of air, or from the inspiration of pernicious gases, oxygen gas may be inhaled with advantage. From the same reason, it has been recommended in spasmodic asthma, attended with danger of suffocation. Still it is, at the best, a mere palliative, and can by no means prevent renewed attacks. If we consider, in the application of oxygen gas, its physical action, as already discussed, we shall readily conclude that the inspiration of oxygen is in most cases useless, and that but little—and only in few cases—can be expected from its therapeutical application.

Nevertheless, an "Inhalatorium," recently opened in Berlin, sells oxygen at 6 silver groschen per cubic foot (20 marks per cubic meter) and oxygenated water at $1\frac{1}{2}$ silver groschen per bottle.§ As water 0° does not absorb 4 per cent. of its volume, a half-liter bottle does not contain 20 c.c., or 0·0017 grm., of the gas. To expect any effect from such a dose appears irrational.

Just as concentrated food is recommended for travelers, so oxygen has been proposed to be inhaled by those who climb the highest summits of mountains or attain altitudes in balloons where the rarefaction

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* Pereira. "Heil Mittel Lehre:" Buchheim's German edition, vol. i, p. 217.

† Verbal communication from Professor Oscar Liebreich.

‡ "Considerations on the Use of Factitious Air and on the Manner of Obtaining them in Large Quantities," by F. Beddoes and J. Watt; Bristol, 1794–95. It is well known that, in 1798, a Pneumatic Institute was founded at Bristol, in which the medicinal properties of gases were examined, and where Humphry Davy discovered the effects of nitrous oxide.

§ Eight silver groschen = four-fifths of a shilling sterling..

of the atmosphere occasions dangerous affections.* P. Bert† has exposed himself and others, in a suitable apparatus, to dilutions of air far surpassing that encountered at the greatest altitudes hitherto reached. The difficulty of breathing, and the symptoms of suffocation which appeared when the barometer indicated 300 to 250 m.m. were relieved, according to his account, by a single inspiration of pure oxygen. Dilution of oxygen with atmospheric air was found more advantageous than the pure gas; and on a balloon voyage which Croce-Spinelli and Sivel undertook from Paris, March 22d, 1874, they took with them mixtures of 45 and 75 per cent. of oxygen (and therefore 55 and 25 of nitrogen.) With the aid of this mixture they were able to conduct valuable physical observations at leisure, and without bodily inconvenience, at the height of more than 6000 meters; and although Glaisher succeeded, without this auxiliary, in attaining still greater heights, it cannot be denied that oxygen gas affords the means of exploring atmospheric regions hitherto unknown.

The physiological applications of oxygen lead us naturally to that modification which bears the name of ozone, with which, in the outset, high therapeutical hopes were connected.

The discovery made known by Schonbein, according to which the peculiar phosphorous odor accompanying the electrolysis of water was due to the evolution of oxygen in a state possessing heightened oxidizing properties, was received with great expectations, both in medicine and arts. Schonbein named this oxidizing principle ozone (from *ὄζειν* to smell), and he perceived its evolution, as Van Marum had already done in 1785, at least, as far as the odor is concerned, near the conductor of an electric machine when in action. He discovered subsequently that it was produced also during the slow combustion of phosphorus, and that it was present in the atmosphere in very perceptible traces. Observations of its occurrence increased very rapidly. Schonbein and others found that the peroxides of silver, barium, and hydrogen, in contact with sulphuric acid, evolved oxygen more or less strongly ozonized, the same property belonging also to the manganate, permanganate, and (according to Rammelsberg) the periodate of potash. The agitation of air with mercury, or with the precious metals in a state of fine division, or with powdered glass,‡ was also

* Fonvielle, "La Science en Ballon:" Paris, 1869.

† Bert, *Comptes Rendus*, 1874, p. 911.

‡ Andrews, *Nature*, 1875, p. 365.

found to be a means of ozonization. The ethereal oils, especially oil of turpentine, display this property in a high degree. Ozone was detected in the air current from a furnace-blast and in the oxygen expired by plants.

The means for its detection, in addition to the fact that 1 part of ozone imparts its peculiar odor to 500,000 parts of air, were found in the following reactions :—

Ozone liberates iodine from the iodide of potassium, iodic acid and potassic peroxide being simultaneously formed, and the solution, after the removal of the iodine, has an alkaline reaction. The presence of the free iodine is easily demonstrated by means of moist starch-paper, and the potash, or potassium peroxide, by litmus. Ozone bleaches indigo and colors freshly-prepared tincture of guaiacum a deep blue, turns paper brown which is saturated with salts of manganous oxide or thallous salts by the formation of higher oxides, oxidizes mercury at ordinary temperatures, and converts silver into black silver peroxide. Paper saturated with thallous oxide and exposed to ozone blues tincture of guaiacum, potassium-iodide, and starch before it turns brown. It was sometimes forgotten that the reactions with indigo, guaiacum, and iodide of potassium and starch are produced also by chlorine, nitrous and hyponitrous acid, and hence phenomena have been ascribed to ozone which were really due to one or other of these bodies.

Concerning the nature of ozone, opinion fluctuated for a long time. More than one eminent chemist held that it contained hydrogen. Marignac and De la Rive maintained the opposite view, which was finally demonstrated by Soret in 1863. The reason of the difference between ozone and ordinary oxygen became gradually intelligible. The first step was furnished by the observation of Andrews and Tait that ozonized oxygen if heated to 270°, was converted into common oxygen, increasing at the same time in volume, and that ordinary oxygen, if ozonized by silent electric discharge decreased in volume. This decrease in bulk corresponds to the quantity of the active oxygen absorbed by potassium iodide, so that if the volume, on ozonization, is decreased by $\frac{1}{n}$, then $\frac{1}{n}$ of the ozonized oxygen is absorbed by solution of potassium iodide. Ozone, therefore, appears indubitably as condensed oxygen. Odling's hypothesis that this condensation amounts to one-third, and that the molecule of ozone is larger by the

half than that of ordinary oxygen, its molecular weight being $O_3 = 48$, that of common oxygen being $O_2 = 32$, was approximately proved by Soret in 1865, and decidedly demonstrated by Brodie in 1871.* Soret added the discovery that ethereal oils, especially oils of turpentine and of cinnamon, absorb the whole amount of the ozone formed; consequently, not $\frac{1}{n}$, but $\frac{3}{n}$.

Ozone has never been obtained in a state of purity.

All chemical methods, as well as the electrolysis of water, yield it only very sparingly, since not merely reducing agents, but even oxidizers—all super-oxides for instances—re-convert ozone into ordinary oxygen. The example of barium super-oxide shows this in the following equation :—$O_3 + BaO_2 = 2O_2 + BaO$.

Connections of cork and caoutchouc cannot be used in an ozone apparatus, on account of their oxidisability. The electric spark has also a destructive action upon ozone. The best procedure for its preparation is, therefore, silent discharge with the aid of a Ruhmkorff's apparatus in induction tubes, filled with oxygen. The greatest contraction which Andrews and Tait observed in oxygen thus treated was one-twelfth. This, as has been shown above, amounts to the transformation of one-fourth of the oxygen present into ozone.

An instrument of this kind, of a simple construction, was described by Warner Siemens† in 1857. Brodie‡ has recently defended the claims of this eminent physicist in opposition to supposed recent inventors, especially Houzeau. Wills‖ gave the instrument a less fragile form, and with this modification it has been recently introduced into trade by the English mechanicians, Tisley and Spiller.§ It has the advantage that it can be cooled by the passage of a current of water. As Siemens recommended the application of the thinnest possible glass it remains to be decided whether the more solid form may not involve a reduction of the yield of ozone.

(To be continued.)

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*Brodie, *Proceedings of the Royal Society*, vol. xx, p. 472, 1872; Odling, "History of Ozone," *Proceedings of the Royal Institution*, 1872.

†Siemens, *Pogg. Ann.*, cii, 120.

‡Brodie, *Nature*, Feb. 18, 1874.

‖Wills, *Ber. Chem. Ges.*, vi, 769.

§*Nature*, viii (1873,) 148.

PNEUMATIC TELEGRAPHS FOR LONG DISTANCES.

Paper read at the Meeting of the Society of Civil Engineers of Paris, on the 4th of June, 1875.

By M. A. Crespin.

The pneumatic telegraph, whose origin dates from an already remote period, has during the last twenty years been in numerous cases brought into practical use, the first application of the system having been made in London, by Latimer Clark. That city now possesses the most complete arrangement of the kind. The very important traffic of the great commercial centre requires arrangements of a special description, which have been carried out with the greatest success by the engineer-in-chief of the post office, Mr. Culley, and by Mr. Sabine.

After London; Berlin, Paris and Vienna have successively adopted the new means of communication, and have laid down similar systems of tubes for the service of internal messages.

The favor which this new system, which cannot pretend to vie with electricity in point of capacity, has found, is owing solely to the peculiar conditions which arise in the majority of great cities, that is to say, that the telegraph service is, in such cases, called upon to transmit a large number of messages over distances comparatively very short. Under such circumstances, electricity is surpassed in speed by modes of transit whose action is much less instantaneous, but whose capacity for transmission is very much greater.

In order to render this rather abstract explanation more complete, I will take for example the case of a telegraphic wire having to transmit a certain number of messages over a distance of no more than one thousand meters, and I will compare with it a pneumatic tube performing a similar service. The wire will transmit the messages one by one, and it will not be able to send more than forty in an hour; a clerk must be employed at each end. By means of the tube the distance will be traversed in one minute, and a hundred messages can easily be carried; these messages can besides, be the actual manuscripts, can be secret, and the apparatus being only affected by the bulk and weight of the messages, no matter how many words may be contained in the message, the transmission is equally rapid, and but two attendants are required. The case cited above is one in

which the tube has a most incontestable advantage over the electric wire. It is easy to perceive that this advantage diminishes as the number of messages to be transmitted decreases, and it diminishes also as the distance which separates the two points increases. There arrives, therefore, a time when the wire regains the advantage; that is, when it is able to transmit all the messages which have to be forwarded in a shorter time than it would take the tube to convey them over the same distance.

This method of collecting and distributing messages in great cities gives excellent results in all cases where the traffic is considerable. The arrangements established in the different cities vary according to the method of working, but the principle is always the same, and may be summed up as follows: A tube, as perfectly round as possible, connects the two points which are to be placed in communication; one or more boxes (carriers) containing the messages are introduced into the tube by an apparatus the essential features of which are always the same; that is to say, the tube is closed behind, and a branch tube opening into the main tube between the end of the latter and the train (boxes or carriers), directs a current of compressed air into the tube, producing a pressure H greater than the atmospheric pressure h, which acts at the other end. It is under the influence of this difference of pressure, $H - h$, that the train is driven forward along the line, continually receding from the point at which the compressed air is introduced.

When a message has to be brought in the reverse direction, the same point is placed in communication with a reservoir, in which the pressure is less than the atmospheric pressure h, which acts at the other end. $H - h$ is now negative, and the train placed at the extremity of the line is drawn back to the original point of departure, where it arrives at the end of a certain time. The suction of air is then stopped by the simple closing of a stop-cock, and a door similar to that used for the sending, allows the train to be taken out of the tube. An electrical communication is provided, by means of which the attendants placed at the ends of the table are able to control and direct all their operations.

The method employed for compressing the air and producing the vacuum may be any one of the methods by which this class of work can be performed. It appears, however, after different trials, that

steam-engines, with direct-acting air-pumps have been found to work with the greatest regularity, and have consequently been adopted almost universally in cities possessing pneumatic telegraphs.

As regards the circulation, this is effected either by a circular network, worked continuously or alternately, according to the importance of the traffic, or by a radiating system worked in the same manner. In both cases pressure is used for impelling the trains forward, and vacuum for drawing them inwards. The radiating system seems to have been established at the commencement, as being the most simple, and it has been maintained where the traffic is very important, on account of its affording a service of the most direct character. The largest system of this kind is that of London, where special arrangements are made by which the tubes are traversed by continuous currents of air into which the boxes or carriers to be forwarded are introduced by means of a species of sluice, the boxes received being taken out as they arrive, by the same means. One of the first systems proposed for Paris, in 1860, by M. Antoine Kieffer, was arranged in the same way.

Pamphlet by M. Amédée Sebillot.—In 1866, when the first pneumatic lines were established in Paris, this system was not adopted, and the first works of the kind, executed in Paris by MM. Mignon and Rouart, were carried out upon the network principle, and worked by intermittent currents of messages at regular intervals, a mode of working which is more economical than the former, although rather less rapid.

After this short descriptive account, I come to the object of my paper. In the first place, I propose the following question:

What are the laws which regulate approximately the movement of boxes in pneumatic tubes?

Experiment shows that the presence or absence of the train in a tube has but little influence upon the flow of the air; that the flow takes place under conditions almost identical with those which govern the flow of other fluids, and that the laws which are observed to prevail in the case of these other fluids can, without risk of too much error, be applied to the particular case now under consideration.

Let R be the resistance to the movement, l the length, X the perimeter, u the speed, a and b coefficients; the approximate formula for the flow of fluids is—

$$R = l\,X\,(a\,u + b\,u^2)$$

Disregarding the term where the speed is in the first degree, the formula becomes—

$$R = b\ l\ X\ u^2$$

The force which causes the boxes to move, being equal to the difference of pressure $(H - h)$ multiplied by the section S upon which it is applied, the formula of the movement will be approximately—

$$(H - h)\ S = b\ l\ X\ u^2$$

which in the case where the section is a circle, becomes—

$$H - h = \frac{8\ b\ l\ u^2}{D} \therefore u = A\sqrt{\frac{(H - h)D}{l}}$$

A formula which numerous experiments have shown to be sensibly correct for the conditions under which pneumatic tubes are usually established and worked, and which shows that the speed varies as the roots of all the conditions of the case, directly for pressure and diameter, universally for length.

As we are considering the means to be employed in order to construct a line of a length l, as great as possible, let us examine successively the influence of each of the forces or dimensions which affect the speed under these conditions.

The first thing to examine is certainly the pressure, or rather the difference of the moving pressure $(H - h)$. The general formula shows that if we were to increase $(H - h)$ and l in the same proportion, a constant speed would be obtained.

Unfortunately, this simple solution is an impossible one, for the practical means at our disposal do not allow of air being compressed at a sufficiently low cost; beyond a certain limit, which is 1 effective atmosphere) or 2 atmospheres at most, the cost of compressing (owing to the great outlay necessary), is so considerable that if such a method of working were adopted, even supposing no obstacles were encountered from the elevation of the temperature and the moisture of the air, it would be impossible to organize a remunerative service. A limit would besides be quickly reached, for even by very costly processes, it is with the greatest difficulty that a pressure of from 5 to 6 atmospheres can be exceeded.

In the same way with vacuum. In continuous working, a vacuum of much more than 0·50 meters of mercury cannot be depended upon. In conclusion, a pneumatic line arranged for economical working

must not require a pressure of more than 2 atmospheres at most, nor a vacuum of more than 0·55 meters of mercury.

The second point to be examined is the diameter of the tube. Here it seems evident that no mechanical difficulty prevents a considerable increase ; the formula shows that by increasing in the same proportion as the length, a constant speed will be obtained ; experiment confirms this conclusion satisfactorily as regards the speed, and, in fact, the speed is generally found to exceed that shown by the formula. Unfortunately this plan would be too costly ; it would result in the laying of very large tubes between points very far apart, even when the traffic between these points might be very small. Now, the cost of laying a pneumatic line increases very quickly with the diameter ; much faster than the diameter, and the cost of working increases more quickly than the square of the diameter. It follows, from what has been previously stated, that, in laying a pneumatic line, the only point to be taken into consideration in fixing the diameter of the tube, is the amount of the traffic to be conveyed by it, and we shall see further on, that to accommodate an important traffic, it is not necessary to exceed a section which, at first sight, appears extremely small.

In examining arrangements of this nature, one is astonished at the small diameter of the tubes generally adopted ; thus, in the great English system at St. Martin's-le-grand, the diameter of the tubes is almost exclusively $2\frac{1}{4}$ inches. Two lines only, the traffic of which is exceptional, and upon which up and down arrangements have been adopted, have been made 3 inches in diameter. The expenditure of air in these tubes is double that in the others, and consequently the English engineers have restricted their use as much as possible.

What is the reason for a size which at first sight appears so small ? The answer will be found in examining the conditions under which the line itself is established.

A telegraph message or a pneumatic letter is always very limited in its size and weight, the amount of matter daily sent through pneumatic tubes by a population of one or two millions of inhabitants is represented by a bulk and weight far from great, and when the comparatively rapid speed with which this matter is passed through the tube is taken into consideration, it is easy to see that it is not at all necessary, in a successful system, for them to be of large dimensions.

Let us make a comparison between the tubes under consideration

and other mains or tubes carried underneath the soil in large cities for distributing gas and water, the latter of which, in well supplied towns is furnished to the inhabitants at the rate of about 100 liters per head per day. To afford this, supply mains of about a meter in diameter are employed on the chief routes, and of a smaller diameter on the others; the speed of circulation is at most one meter per second. In the case of the matter conveyed in the pneumatic tubes the amount certainly does not exceed 1 gram for each inhabitant, or one thousand times less, and the speed in the pneumatic tubes is at least ten times as great; with a section of one millionth, we shall then have made the conditions nearly equal.

If we apply these figures to Paris we find a mean circulation of 10,000 messages per day of 5 grams each, making a total weight of 50 kilograms: these messages distributed into boxes, for passage through the tubes, at the rate of 25 per box, would require 400 boxes or 40 boxes per hour, which could easily be forwarded in four trains dispatched at intervals of a quarter of an hour. It is clear that trains might be sent at much more frequent intervals provided, of course, that sufficient power were employed to produce the compressed air and vacuum which would be required.

The tubes employed in Paris have a diameter of 0·065 meters, and would certainly suffice for a traffic of 50,000 messages per day, if the need for carrying so large a number of messages arose.

(To be continued.)

PRODUCT OF SUGAR IN LOUISIANA.

The actual results from cultivation of sugar-cane in Louisiana are exemplified by the following statements:

On the plantation of Messrs. McCall Bros., there was raised from 569 acres of cane plantation, 15,961,384 lbs. of cane, or 28,051 lbs. per acre. The yield of cane juice averaged 7° to 8° Beaumé density and the product in sugar was 506,500 lbs.; in molasses was 516,000 lbs.; or 1000 bbls. of 43 gals. of 12 lbs. per gallon. Total weight, 1,022,500 lbs., equal to $6\frac{4}{10}$ per cent. of the cane worked.

On the plantation of Col. Amedée Bringier there was obtained from 51 acres of selected cane plantation, 2,947,500 lbs. of cane or 57,794 lbs. per acre. The yield of cane juice was 8° Beaumé, and the product

in sugar was 135,272 lbs.; in molasses 74,976 lbs.; total weight, 210,248 lbs., or 7·13 per cent. of the cane juice. The great preponderance of sugar over molasses in this case is ascribed, first, to the good condition of the cane, and secondly, to the superior treatment of the cane juice in the boiling processes; [but it should be added that the usual ratio of sugar to molasses in first strikes for Cuba or Beetroot practice is as 2 to 1 (of molasses of 12 lbs.)]

On Evan Hall plantation, of Harry McCall, Esq., was produced for the season of 1874–5, "7599 loads of canes weighing 22,204,670 lbs. The yield of cane juice was 1,417,800 gallons of a density of 7° to 8° Beaumé, (12,505,000 lbs). Evaporated to 25 per cent. Beaumé hot, the result was 274,000 gallons of syrup. (2,740,000 lbs.) Mr. McCall estimates the product of this to be (first strike only for New Orleans molasses is so valuable as to preclude making 2d or 3d sugars) 900,000 lbs. of sugars and 700,000 pounds of molasses." His estimates are shown in the following table:

Total of Saccharine of the density of Sugar.	First Sugar.	Molasses of 30° Beaume, = 55 per cent. of Saccharine, = 12 pounds per gallon.		Syrup of 25° Beaume, = 46 per cent of Saccharine, = 10 pounds per gallon.		Raw Juice of 7° to 8° Beaume, = 13 per cent of Saccharine, = 8·82 pounds per gallon.		Pounds of cane.	Product of cane.
Lbs.	Lbs.	Lbs.	Galls.	Lbs.	Galls.	Lbs.	Galls.	Lbs.	Acre.
5·80	4·05	3·15	0·26	12·15	1·22	55·	6·22	100·	
1·43	1·	0·78	0·065	3·	0·3	13·6	1·54	24·7	
4·77	3⅓	2·6	0·22	10·	1·	35·3	5·13	82·3	
	1134		70·8		341·6		1741·6	28,000.	1

[The estimates of this table are scarcely compatible with each other, and indicate some want of care in taking the density of the raw juice or great loss of density in defecation and skimming. 55 lbs. of raw juice of 7½° Beaumé density ought to give 16·1 lbs. of syrup of 25° Beaumé, or not less than 15·9 lbs. with a large allowance for

skimmings. 12·15 lbs. of syrup of 25° Beaumé ought to give 4·05 lbs. of sugar, and only 2·8 lbs. of molasses of 12 lbs. per gallon. As the result is *estimated*, it is impossible to correct the densities from it, but it is probable that the syrup was boiled to 27° or 28° Beaumé, and that the raw juice was about 6½° on the average.]

There was consumed in working off this crop on the Evan Hall plantation, 8600 barrels coal and 800 cords of wood. (These quantities do not reduce themselves to common units of value in any satisfactory way.)

Mr. McCall states in reply to the question, "How much it costs to cultivate an acre of cane?" "It is very difficult to give a satisfactory answer. Inasmuch as to raise cane, we are obliged to rotate with corn and peas, and each acre of cane, besides this year's cultivation, represents earlier work. As nearly as it can be come to, it can be said that it costs $80 per acre, all cultivation thrown in. As to what it costs to lay down a ton of cane in the shed, that is also difficult to state. Perhaps, however, in saying it costs $4 per ton we should not be much out of the way."

Of the present condition of sugar raising it can be said that, while in former times 10 hhds. (1150 lbs. each) were reckoned to a farm hand, since the war, 5 hhds. to the hand have rarely been exceeded. As a basis of estimate for the profit of the cultivation of cane it can be assumed that a good hand can easily cultivate 10 to 12 acres a year which should yield ¾ to 1 hhd. of sugar.

ON A SIMPLE METHOD OF COMPARING TWO SOUNDING AIR COLUMNS BY MEANS OF VIBRATORY FLAMES.

By Dr. Bresina.

(*Translated from Poggendorf's Annalen by C. B. Dudley, Ph. D.*)

The comparison of the vibrations may be accomplished, as is well known, by means of the apparatus constructed by Konig, in Paris. In this, two organ pipes act on two gas flames, one above the other, by means of manometric capsules. The motions of these flames are then analyzed by a rotating mirror.

The comparatively high price of this apparatus aroused in me a desire to accomplish the same thing, in a simpler way, by means of the chemical harmonicon.

Through the investigations of Schaffgotsch, (Pogg. Ann. vol. 101, p. 471), it is known that a flame singing in a tube makes vibrations whose number agrees with the number of vibrations of the column of air. It follows that the vibrations of two columns of air may be compared if the gas flames which are singing in the tubes can be placed perpendicularly, one under the other, and sufficiently near to each other. But the tubes themselves prevent this. I have sought, therefore, to transfer the vibrations of the flames burning in the tubes, to flames burning in the open air. I succeeded very well in this, in the following simple way: On two small stop cocks connecting with the gas pipes on the gasometer, I placed small glass tubes, which had been drawn out pointed at one end, and to the side of which short bits of similar tubing had been joined. These side tubes were connected by means of rubber tubing with two other glass tubes, bent at right angles, which had likewise been drawn out pointed at one end, and had been so fastened to a stand that their openings were in a perpendicular line. If now the gas be lighted at the openings of the four tubes, and larger glass tubes which give harmonious tones, be placed over the flames from the two tubes first described, and the flow of gas properly regulated, the flames in the harmonic tubes will sing, and the two other flames will vibrate with them. These latter flames give in a rotating mirror the beautiful images which so well allow the number of vibrations to be perceived.

It succeeds equally well to allow the two flames which sing in the tubes to act together in one flame which burns in the open air. It is only necessary to fit out a glass tube with a lateral appendage like those on the stop cocks to set this up in the open air, and to connect it with the two rubber tubes. A flame image formed from a combination of the two simple ones is thus very beautifully obtained in the mirror.

Errata to article on moving brick houses, page 178, dele. the circle on wood cut—it has no meaning whatever. Page 180, last sentence of article, read: "Everything was convenient, adapted for the requirement, and ready for use, and the work was done by a gang of seven drilled, practical laboring men."

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EDITORIAL.

The Perpetuation of Error in Text Books.—The lead of the steam valve.

QUESTION 204.—"*Why is it desirable to open the steam-port and admit steam at the end of the cylinder towards which the piston is moving, before the latter has completed its stroke?*

"Because it is essential, in order to insure a good action of the steam, that the maximum cylinder pressure should be attained at the very commencement of the stroke. If the steam-port was not opened until after the piston had commenced its stroke, some appreciable time would be consumed in filling the clearance space and the *steam-way* with steam.* It is also found, especially if an engine is working at a high speed, that a slide-valve worked by the ordinary link-motion will not open the steam-port rapidly enough to enable steam of the maximum boiler pressure to fill the space after the receding piston, unless the valve begins to open the port *before* the piston reaches the end of its stroke.

"Another advantage resulting from the pre-admission of steam consists in the smooth working of the engine at high speeds, a circumstance which reduces greatly the wear and tear of the working gear. As the piston approaches the end of its stroke, the pre-admitted steam forms a kind of elastic cushion, which is well calculated to absorb the momentum of the reciprocating parts at that instant. The pressure due to the momentum of these parts will of course, depend

* The *steam-ways* are the passages which lead from the steam chest to the cylinder, and are sometimes called steam-ports, but the term steam-ways is used to distinguish the passages from their openings in the valve-seat, which latter are more properly called steam-ports.

upon their weight and the speed of working, increasing directly as the square of the speed. It follows from this that the lead should increase with the speed, and that it should be greatest at high speeds. As has been shown before, this condition is fully accomplished by the ordinary shifting-link motion."

The extreme difficulty of eliminating erroneous statements from previous publications, or from translated originals, especially after many reiterations of error, is exemplified in the preceding quotation from a recent text-book.*

The original statement, made by good English authority about the years 1830 to 1835, has held its place in all text-books of succeeding date, has gone to misinform German students on its travels, and has come to America, translated, to impart error here. As a general assertion it may be correct that "it is essential in order to ensure good action of *the steam* that a maximum cylinder pressure shall be attained at the very commencement of the stroke," but as applied to a running engine it is altogether erroneous.

For *easy motion of an engine*, the prevention of shocks, and relief of bearings from excessive pressure, (and consequent friction and loss of power), it is desirable that as the piston approaches the end of its stroke, the exhaust shall have been closed so as to form a cushion that will absorb the momentum of the reciprocating parts and relieve the pressure on the slide-valve at its time of opening; and the back pressure will then be just that needed to give to the moving parts their proper velocity in the other direction. And then, *after the centre is well passed*, the pressure of steam should be slowly admitted, reaching a maximum not earlier (perhaps for high pressure non-condensing engines) than 1-15 or 1-12 of the motion of the crank; while the cut-off should be effected, both for good action of the steam and for the good action of the engine, instantaneously. It may be possible with small sizes of ports, and inadequate cross areas, or great length of passages that steam cannot follow a piston at high speeds, but such possibility exists only with improper proportions for high speed, and should not be remedied by lead.

The original statement of forty to forty-five years since, was not incorrect for the time; and if the conditions are all given, is not incorrect to-day.

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* Catechism of the Locomotive. M. N. Forney, M.E., New York, 1875.

About thirty-five years since, the slide-valve was made without lap; it just covered the ports at both ends. The skill of the workman was taxed to see how exactly the one steam-port should open and the other be closed. The motion then given to the valve was almost coincident to that of the crank, and the rate of opening was exceedingly slow, as both crank and eccentric had just passed their centres. The valve motion was then usually transmitted from the eccentric to the valve through light rocker arms and rods, and there was more or less lost motion in the transmission. Under such circumstances, there was a reason for lead of the eccentric, as well as valve, and both rule and reason had a warrant in facts.

When the lap valves were introduced, much difficulty followed, so firmly had the theory of *lead* been established, but the workmen have long since learned, if the books have not, how to get the thump out of a slide valve engine. After many years of practical experience, the writer does not hesitate to aver that nothing he ever learned cost him so much money and annoyance to *unlearn* as this rule and reason for the lead of a valve.

The effect of throttling the exhaust is no way a loss of power, but is simply a loss of capacity of the steam cylinder. For a given boiler a little larger cylinder is needed to perform the same work. There is, however, an absolute loss of steam and power on the back lead of the steam, and its recompense must be found in the ease of working and duration of the engine.

These remarks do not apply alone to slide-valve non-condensing engines. For engines of higher grade, in economy for use of steam, the cutting off of the exhaust is a great practical gain. With 24 to 26 inches of vacuum, if the exhaust is closed (cut off) at $\frac{1}{4}$ or $\frac{1}{3}$, a back pressure of vapor will pile up in the cylinder to over one-half an atmosphere, and thus relieve, or partially relieve, the engine of the momentum of the piston and parts, (it being premised that the piston *should be* as heavy as possible), and besides this, the condenser will have been relieved from any leakage of the piston itself, which leakage again, will have been saved for effective working of the engine. Leakage of piston packing, within the limit of troublesome back pressure thus becomes tolerable.

THE WATER COMMISSION.

The Commission of Engineers on the Water Supply of Philadelphia, have completed their labors, and their report is now before the City Councils and the public.

It is mainly local in its interest, and will undoubtedly meet with discussion from the city press that will prove instructive to the residents. Still the question was the water supply of a locality, and in this case the locality was one of the very large cities; so large as to occupy a place in the list of a hundred of the largest cities of the civilized world, and a report from six selected engineers, who should adequately treat the subject, should of necessity have possessed an interest beyond our city, land or country. It will, therefore, prove a disappointment to readers, both citizens and professional men, that in this report there is so evident an avoidance of the issues; and such a want of comprehensive view of requirement in future, and even of necessity to-day, and so complete an absence of novelty or individuality in conclusions or propositions.

In the origin of the Commission, it was admitted as unquestionable that there is now a deficiency of water supply in the present courses, pools, reservoirs or apparatus. It was also admitted, that water in the pools of supply is polluted by sewage of premises and manufactories. And further (incidentally perhaps), that the nuisance of sewage is becoming apparent in our rivers near the city, and extending already in evident effect forty or fifty miles below, into the broad bay. The discussion of these leading topics, the investigation of the circumstances now subsisting, the consideration of means for ameliorating the difficulties, the decision on the two points as to what ought to be done eventually, and what ought to be done now; formed subjects of ample importance for a Commission to act upon.

To take the briefest view of the question. The inadequacy of water supply has become painfully apparent to many citizens. The summer minimum supply is under fifty millions of gallons per day. (We think the supply of 1869 much under this). Supposing that this supply is inadequate (and here it is that the commission should have asserted itself positively), the call for new steam apparatus follows at once. The summer minimum quantity in the river is 240 millions of gallons per day. From this it would appear, that one-fifth of the whole water in the Schuylkill may be demanded to afford even the limited quantity named. With the unlimited demand on the

city service, which we now permit to be made by water users, and with the growth of the city in its present ratio, but few years (10 or 15) must elapse before a half of all the water the Schuylkill can furnish in the month of July will be needed for consumption alone. In such case, the quantity of water left in the river available for pumping, will not suffice to lift over 10 or 15 millions of gallons. It follows, that we *must* eventually (and quickly) have steam power equal to nine-tenths of our consumption. And this reasoning is little affected by the proposition to purchase the Flat Rock mill privileges, for they would only in the emergency allow the one-tenth to become three-tenths. The whole scheme of *water* pumping is what is called on the Mississippi river high water pilotage.

It may be demonstrated, that it will pay to use the water power we now own during the six or eight months that we have it, but it would need a careful array of figures to exhibit the fact, and this report does not contain either question in this form, or answer. But even with the six feet extra depth of water in the Fairmount pool (however desirable the head may be for turbines), the continuance of the turbine system of pumping is open to question. From a mechanic's point of view, one cannot discern the propriety of getting up a rotary motion through the complicated machinery of a turbine at high velocity, and gearing down to a reciprocating motion of a piston pump, when it is perfectly feasible (and good practical examples exist to demonstrate the facts) to pump directly by water pressure only. We do not believe that the turbines and pumps are averaging over 45 per cent. of duty, or ever have done so.

Passing from the supply and apparatus, which suggest another report rather than these few remarks, the purity of the water is even more important than the quantity. Here we have an admirable appendix by Col. Adams, who seems to have thought vigorously and soundly on the subject. A counteracting document is, however, found in the appendix of Booth and Garrett, who have cleverly ignored all the conclusions; but we think the sense of the community will side with the engineer rather than with the chemists. Authorities agree in saying that the presence of definite quantities of organic matter *do not* render water unhealthy.

The averment that it is not the quantity but the nature of the organic matter which determines the pollution, is happily illustrated by the remark that ten grains of sewage substance to a gallon might prove

deleterious, while one hundred grains of tea or coffee would be healthful and refreshing. This averment is permitted to lose all its force, by the subsequent assumption, when instituting comparisons of Schuylkill with other waters, that the organic matters present in each *are* the true measure of vitiation. Another assertion of the chemists needs qualification. They say, "River water has been used (as a beverage) from the earliest times without the slightest injurious effect." Take the Illinois river for an example (even before the Chicago sewage emptied into it). We think the residents on its "bottoms" would, as a steady drink, advise whisky!

Recurring to the nature of organic substances in water, we can say positively that water which has generated typhus fever of the worst character, has been found to have but very little organic matter, but the balance of all medical (not chemical) authority is, that in time sooner or later, water contaminated with sewage will become the vehicle of disease of fearful character if not extent.

With this fact before us, it is to be regretted that the recommendation for immediate construction of an intercepting drain to take off the sewage of Manayunk, the Chelten Hills and Germantown did not meet the unanamous approval of the Commission. Should this sewer be built at any future time, it will be found necessary to convey it across the river (under the dam, possibly), and extend it down to the Delaware; for it would never answer to discharge so much sewage as will come from the combination of these sources, together with the Mantua sewage, into the slow tidal stream of the Schuylkill below Fairmount dam.

It would have been very well if the Commission had discussed and expressed an opinion as to the condition of the Fairmount pool, and advised some steps for its purification.

The expectation that purity of water would be ensured in the winter by the removal of a few patches of ice, is too absurd to need argument to refute it. The probability is that a considerable part of the decomposition of Manayunk sewage at that season takes place inside the city water pipes themselves, as there only is the water warm enough to decompose organic matter. At all events denuding one thousandth part of the surface of the river in ice getting, is by no means the exposure which will constitute perfect "ærating" (if that is the right word).

But even if this proceeding effected *all* that could be wished in winter, the low water summer condition of the pool is truly deplorable, and embankment and excavation is immediately requisite. Not only should the flats which are alternately flooded and laid bare by the fluctuations of the stream be removed, and stone walls or gravel banks be established on the margin, but the vegetable matter of the bottom should be dredged to such depth, as will prevent active decomposition of any substances which may be deposited.

The condition of the Delaware point of supply, can only be alluded to say that it is even worse than that of the Schuylkill.

There are other matters disposed of in the report—the slack water system with reservoirs for supply, the Delaware river scheme, and the Perkiomen scheme. But to these the adverse opinion of the Commission will meet general approval.

We should have liked to discuss the nature of the territory which forms the watershed of our rivers, from which we must look for supply; its general aridity, absence of standing water, lakes or ponds, and infrequency of perennial springs (making a deficiency of natural storage), and especially the immediate effect of low dew point upon rainfall, etc., etc.; but the length of this notice compels abrupt termination, as it has compelled assertion rather than explanation or argument.

Announcement of Lectures to be given before the Franklin Institute at their Hall, commencing Thursday, November 4th, 1875:

Six Lectures by Prof. Edwin J. Houston, on Acoustics,
November 4th, 11th, 18th, 25th, December 2d, 9th.

Two Lectures by William H. Wahl, Ph.D., on Gas Lighting,
December 7th, 16th.

Four Lectures by Mr. D. D. Willard, on Mathematics,
November 9th, 16th, 23d, 30th.

Two Lectures by Theo. D. Rand, Esq., on Mineralogy,
December 14th, 21st.

The order of Lectures after the holidays will be given in good season:

One Lecture by C. B. Dudley, Ph.D., on Artificial Ice.
Three Lectures by Prof. P. E. Chase, on Natural Physics.
Three Lectures by Mr. Robert Briggs, on Steam Boilers.
Two Lectures by Prof. D. Cope, on Paleontology.
One Lecture by Mr. Jos. Zentmayer, on The Lens.
Two Lectures by Prof. R. E. Rogers, on Chemical Force.

Besides these, there will be a number of Lectures, the Subject not yet fully decided upon, but which will be announced in due time.

Franklin Institute.

Hall of the Institute, Oct. 20th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present two hundred and thirty-three members and thirty-seven visitors.

The minutes of the stated meeting for September were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their meeting held on the 13th inst., there were six persons elected members of the Institute and the following donations made to the library:

Explorations of the Colorado River of the West and its Tributaries. Explored in 1869, 1870, 1871 and 1872, under the direction of the Secretary of the Smithsonian Institution. Washington, 1875. From the Secretary of the Interior.

The Uranian and Neptunian Systems, investigated with the 26-inch Equatorial of the United States Naval Observatory, by Simon Newcomb, LL.D. Washington, 1875. From the Author.

Jahrbuch der K. K. Geologischen Reichanstalt. Vol. 25, January to March. Vienna, 1875.

Verhandlungen d. K. K. Geologische Reichsanstalt. Nos. 1 to 5 inclusive. 1875.

Die Culm Flora des Mahrisch—Schlesischen Dachschiefers von D. Sturr. Vienna, 1875. From the K. K. Geological Society.

Forty-second Annual Report of the Royal Cornwall Polytechnic Society, 1874. From the Society.

Third Annual Message of William S. Stokley, Mayor of the City of Philadelphia, with the Accompanying Documents, June 24, 1875. From the City Government.

Transactions of the Royal Irish Academy. Vol. 25, XI. Report on the Strength of Single-riveted Lap Joints, by Bindon B. Stony, M.A., with Tables and Plate XXV. Dublin, 1875. From the Society.

Quarterly Weather Report of the Meteorological Office. Part I, January to March, 1874. Report of the Meteorological Committee of the Royal Society for the year ending December 31, 1864. From the Meteorological Committee of the Royal Society, London.

Amphiorama ou la Vue du Monde. 2me Notice la Marée dans le Bassin du Spitzberg et le flat qui contourne la tête du Groen-

land; aussi l'arrivée de la lumiere au pôle pour la premiere fois observé et decrit, par F. W. C. Trafford. Zurich, 1875. From the Author.

Tables, Meteorological and Physical, prepared for the Smithsonian Institution by Arnold Guyot, P. D., etc. Washington, D. C. From the Smithsonian Institution.

Bulletin of the National Association of Wool Manufacturers, July to September, 1875. Boston, Mass. From the Association.

Annual Report of the Board of Regents of the Smithsonian Institution for the year 1874. Washington, D. C. From the Smithsonian Institution.

The Actuary also reported that in accordance with the recommendation of the Committee on Science and the Arts, the Board of Managers have awarded the Scott Legacy Premium and Medal to R. B. Goodyear for his improvements in box motions for looms.

The Secretary read from the minutes of the Board of Managers the report of the Committee on Publication in relation to reprinting the reports on "Steam Boiler Explosions" and "Strength of Materials," and the action of the Board adverse to the reprinting, and also to the expenditure of $1000 for making tests of iron and steel, and on motion, this action was approved.

The Committee on the letter of the British Minister to the United States, in relation to the Albert medal of the Society of Arts, presented the following report, which was adopted, with the appended resolution:

The committee to whom was referred the consideration of what should be done in relation to the request of Sir Edward Thornton, "that the Institute should present to the Society of Arts, London, the names and testimonials of persons eminent in the arts who could be recommended as worthy of the 'Albert medal,'" ask to report:

That the nomination of such gentlemen is in the opinion of your committee a subject of great delicacy, and that however honorable the endorsement and advocacy of the Institute might be, the public announcement of the fact, unless followed by the desired result, would be a source of annoyance to those whom it sought to advance.

Any person who should become the recipient of such an acknowledgment of ability and merit, would be more gratified by ignorance of the steps which promoted it, and would feel aggrieved to be informed of cavils or personalities that may have ensued.

When we examine the record of the lives and thoughts of our eminent men of former days, it is noticeable how detraction and calumny, bickerings and discontent have followed them in some proportion to their very superiority, and it is desirable that such may

not find public expression in prelude to the declaration of opinion from *our* Institute to the Society of Arts.

The Institute at a yearly election chooses a Board of Managers, to whom it confides its interests in various ways, and it seems to your committee that the choice of persons worthy of honor had best be referred to them, and that in this particular the expression of opinion by the Institute can be safely placed in their hands.

As a parallel case we instance the nomination for honorary membership, which is effected by the Board of Managers, who send the names to the Institute for subsequent election and ratification by vote. Similarly, the nomination of gentlemen who would honor the medal proffered by the Society of Arts, could with propriety be made to the elective body—in this case, the Society of Arts—and if the result is the donation of the prize, the instrumentality of the Institute would then become public.

With these views the committee submit the attached resolution, and ask to be discharged.

ROBERT BRIGGS,
B. C. TILGHMAN,
S. W. ROBERTS.

Hall of the Franklin Institute, Phila., Oct. 20, 1875.

RESOLUTION.

Resolved, That the Board of Managers are hereby requested to consider and act upon the communication of Sir Edward Thornton relating to the "Albert medal," and in behalf of the Institute recommend such persons as in their judgment are worthy to be associated publicly with those eminent men who have already received this evidence of estimation.

THE COMMITTEE on establishing a Museum of Industrial Art in Philadelphia, presented the following report, which was adopted:

The project of establishing a museum, having for its object the advancement of the industrial arts, is one in which the Franklin Institute, above all other educational institutions, should take an active part, as no better means could be devised for carrying out the objects for which it was organized, than by bringing together specimens of products of the various industrial arts from the earliest period down to the present time, and showing by comparison the wonderful progress made during the various periods of the world's history. This can only be done by founding such a museum, as it is now proposed to do, and it is fortunate for us that so many of the means necessary to make it successful, are all ready at our hands. The act of the State Legislature, authorizing the loan of a million of dollars, and creating the State Board of Supervisors, was to erect a memorial building to be used as a museum for all time, and this building has

been planned with a view to its adaptation for the purposes of an art museum, and competent persons have declared it to be most admirably adapted to the purpose.

A committee of citizens was organized for the purpose of applying to the proper authorities for the use of memorial building for this purpose, and through the kindness of its Chairman, Dr. Wm. Pepper, your committee were invited to be present at a meeting held on the 7th inst., at which the matter was fully discussed, and a plan of organization was adopted, and on the 12th inst., it was laid before the bodies having charge of the building, consisting of the State Board of Supervisors, the Park Commission, and the city officials, and was referred by them to a committee consisting of the Hon. Alex. Henry, of the State Board, Theo. Cuyler, Esq., of the Park Commission, and John L. Shoemaker, Esq., of the City Councils, and the Hon. M. McMichael, the Chairman of the meeting. These gentlemen have the matter in their charge, and will report to the committee of citizens at some future time, and which your committee most sincerely hope may be in favor of the plan of organization proposed, and asking to be continued, we remain

J. E. Mitchell, *Ch'n*,
John Sartain,
Coleman Sellers,
J. B. Knight.

Mr. Solomon W. Roberts announced the death of Mr. Wm. E. Morris, civil engineer, a life member of the Institute, and gave some account of his life and service, and moved the adoption of the following:

Whereas, William E. Morris, civil engineer, an old and highly respected member of the Franklin Institute, died suddenly of disease of the heart, on Friday, October 15th, 1875, in the 64th year of his age.

Resolved, That the Franklin Institute deeply regrets the death of Mr. Morris, by which it has lost a valued member, and the city of Philadelphia a highly respected and eminently useful citizen.

Resolved, That in his professional career as a civil engineer, for a long period of years, Mr. Morris has shown great industry, strict integrity, and marked ability, and has left a reputation for uprightness and trustworthiness which is well worthy of record and of imitation.

Resolved, That a copy of these resolutions be signed by the officers of this meeting, and transmitted to the family of Mr. Morris.

Mr. Coleman Sellers seconded the motion, and expressed the wish

that Mr. Roberts would prepare his remarks for publication: whereupon the preamble and resolutions were adopted.

The Secretary presented his report on novelties in science and the mechanic arts, embracing Brayton's Ready Motor, or High Pressure Gas Engine, and by the aid of the lantern, gave a description of it, and with the assistance of the inventor, illustrated its principle, and the mode of operating it.

Also, The National Timber Preserving Company's apparatus for impregnating timber with antiseptics, by forcing a solution through the pores of the wood.

The Secretary stated that the commission on the water supply of the city had completed its labors, and that he had been presented with a copy of their report, which he presumed would soon be ready for distribution.

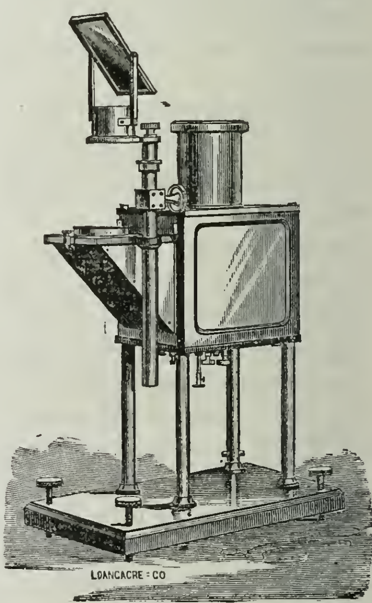
Mr. Edward Brown offered the following, which was adopted:

Resolved, That the Secretary be requested to send notice of the Centennial Exhibition to kindred foreign societies, and extending the privileges of our reading room to their accredited members, at the discretion of the President.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

A New Form of Magic Lantern.—As some of our readers are no doubt interested in the subject of magic lanterns, as they have of late years been developed into philosophical instruments for the demonstration of the principal phenomena of optics, we publish in this place a late report of the Committee of Science and the Arts, on one of these, which seems to have achieved the widest reputation, together with a wood-cut of the same, which has been furnished to us by the manufacturers, Messrs. Geo. Wale & Co., of Hoboken, N. J.



Hall of the Franklin Institute,
Philadelphia, May 30, 1875.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the College Lantern, and attachments, of George Wale & Co., report that they have examined the articles specified, and find them worthy of high commendation. The lantern itself is convenient in size, tasteful in design, and of ingenious construction. The frame is of heavy brass, the sides being of sheet metal, and screwed upon it. The general workmanship is good, and the finish sufficient for apparatus of this kind.

The point of special merit, however, is the very simple and satisfactory device adopted for converting the horizontal lantern into a vertical one. This is effected by hinging horizontally the plate which carries the anterior lens of the condenser. By throwing this up into a horizontal position, and placing the inclined mirror in the space thus formed, a most excellent vertical lantern field is obtained. The attachment of the arm which carries the objective to this movable plate, is also an ingenious and effective arrangement. The polarizing attachment appears also to be worthy of special mention. Its position and the facility with which it may be put in place, and operated, are points of real practical value. The microscopic and spectroscopic attachments are well arranged, and do their work in the most satisfactory way. In use the lantern performs admirably, giving a bright and uniformly illuminated field, with all the above mentioned attachments.

It may be used equally well for the oxyhydrogen or the electric light, the body being mounted on four upright pillars.

The committee believe, therefore, that the College Lantern, manufactured by George Wale & Co., is the best lantern of high grade which is for sale in the country. It is an excellent piece of apparatus, exceedingly well arranged, and convenient. It has a great variety of attachments, which can be readily and rapidly fitted to it, thus making it really a universal lantern. To this opinion, the committee would add that of several distinguished scientific gentlemen, entirely competent to judge of its merits, having had it for some time in use. Their testimony is universally and strongly favorable.

In consequence of the above-mentioned advantages of the College Lantern and its attachments, the committee recommend the award to Messrs. George Wale & Co., of the Scott Legacy Medal and Premium.

(Signed.) George F. Barker, *Chairman.*
Chas. H. Mills,
Chas. Bullock.

By order of the Committee on Science and the Arts.

J. B. Knight, *Secretary.*

Goodyear's Improvement in Shuttle Box Mechanism.

HALL OF THE FRANKLIN INSTITUTE.

Philadelphia August, 27th, 1875.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination, the application of Robert Burns Goodyear, for Improved box motion.

Report: After visiting several factories where these improvements are in daily service on power looms and investigating the state of the arts, find this improvement in drop box looms, is the subject of Letters Patent of the United States, No. 144,089, dated October 28th, 1873 and denominated, "improvement in shuttle box operating mechanism," and its object is to effect the various adjustments of the drop-box of looms, for weaving the description of goods known by the name of checks, or ginghams; and of all the materials in common use for cloth, as cotton, woolen, linen, and silk, or a mixture of them. The check is formed by having the warps striped in a certain order, by warping yarn of different qualities either as to number or color, and crossing these stripes in weaving, at the proper intervals to form squares, with the corresponding kinds of weft; checks therefore are woven with a variety of shuttles, corresponding to the number of colors, or kinds of yarn used as weft, to form the pattern with the warp. The shuttles therefore must be changed, for the purpose of weaving with them, and this is done, by rendering the box which contains them movable, at least at one end of the lathe, and forming the box with a separate berth for each of the shuttles, the movement of the whole box is therefore made in a certain measured manner, corresponding to the breadth of each of the separate berths, so that any of the shuttles, may be brought as required, to the plane of the race and the reed, and used till another change becomes necessary, these changes are regulated by an index or pattern wheel.

There are three methods in common use in which the box is made for effecting the required change of the shuttles. By one method, it is made to slide vertically, with the berths or shuttle box shelving above each other, parallel with the race, this is called the drop-box and was invented by Robert Key in 1760. Another method is the swing box, which is made to vibrate horizontally in the plane of the race, by being attached to a pendulous framing, supported on pivots from the lathe, and Dr. Cartwright has the merit of this invention patented in 1792.

Another method, is the revolving box, patented by W. Boyd of Connecticut in 1828. It was not however until the year 1830 to 1835, that light fancy fabrics with small patterns began to be exten-

sively introduced in manufactories. Checks and ginghams are generally heavy made fabrics, about the set of calicoes; and therefore no special adaptation of the looms is necessary for them, excepting that dependent on the motion for changing the shuttles. The first method, or drop-box, from its stability of action, is the one adopted by Mr. Goodyear, and the mechanism for moving this kind of a shuttle box is the object of his patent. The number of plans that have been tried for moving shuttle boxes, is very numerous, and by far the largest number of them have not succeeded. The essential features in a complete power loom for making the various kinds of checks and ginghams are an index for the pattern, which must have an extensive range such as can only be attained by using an endless chain; the mechanism for shifting the shuttle box, must be so made, that any shuttle can be brought into play, so as to make any pattern that can be imagined. If the box is not brought to its proper position when shifted, there must be a protection, to stop the loom to prevent damage being done to the shuttle box, or the mechanism must be so contrived within itself as to become a protector. The shuttle box must be free from all injurious influences of a dangling, or uncertain action.

By the peculiar construction, as will be readily seen by reference to his patent. Mr. Goodyear has essentially filled these conditions, and in practice we find, the shuttle-box operating mechanism to move the boxes with ease and precision, so that the shuttles can be used in the sequence desired; without danger of damage to the mechanism, to the shuttle-boxes, or to the picker motion, and that the pattern is controlled by endless chain, giving any practical range desired.

Mr. Goodyear has devoted nearly 30 years of his life in perfecting looms for weaving, with movable shuttle-boxes, during which time he has made numerous inventions, among which the most notable was an invention in 1848 called the "pins of different lengths" and which placed the box loom far in advance of all previous ones, and almost on a par with the one shuttle loom of that day as to simplicity of action and speed. The pin in the index or pattern wheel prior to the Goodyear invention merely designated a movement of the box from one berth or shuttle to another, resulting in frequent mistakes by putting in the wrong color; thus spoiling the pattern and requiring ceaseless attention and great skill on the part of the weaver, and causing power loom weaving to linger for a long time behind the hand loom. In the Goodyear invention the Index pins were made of different lengths, each length designating a color, thus bringing check weaving by power to a definite principle, and enabling plain cloth weavers to tend these looms, besides increasing the speed of the looms from eighty shots a minute to one hundred and thirty, a speed which is not excelled by any other looms having movable shuttle boxes.

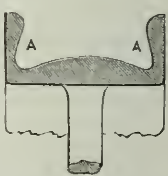
And Committee recommends that the Scott Legacy premium and medal be awarded to Robert Burns Goodyear, for his improvement in shuttle box mechanism, as Patented October 28th, 1873.

Signed, H. F. West.
Coleman Sellers, Oct. 6th 1875. L. L. Cheney.
Barton H. Jenks.

By order of the Committee on Science and Art.

J. B. Knight, *Secretary.*

Flanged Pulleys.—There are some places where the use of flanged sides to retain the belt upon the faces of pulleys, is desirable if not essential. Thus for driving a ball governor, which requires no power whatever when in motion at uniform speed, but demands an application of force sufficient to lift the balls from their position of rest into their place of rotation in the very short interval of time of starting an engine, (which starting is generally without work upon the engine), flange pulleys are almost essential to keep the belt from sliding off the edge of one or the other of the pair of pulleys. For tighteners on some classes of machines and for mule pulleys the same necessity exists. In such cases most machinists have, however, encountered the difficulty especially with long belts, arising from the belt riding upon the flange or its side, and if not running off altogether, of stretching the edge in places and thus destroying the belt rapidly.



By giving the flange the correct shape indicated in the figure, it will be found possible to avoid any of these accidents, and that flanged pulleys will become as serviceable as any others. The shape to be given is simply that obtained by cutting away the base of flange (as at A A) and allowing the edge of the belt to come in contact with the outer periphery only. Pulleys thus formed, present to the unaccustomed eye of a machinist, a somewhat strange look, and except the reason were explained, he would think some bad workmanship had cut away the fillet at the base of the flange improperly. But the fact is positive, and the eye soon appreciates any such essential feature. It may be added that long belts, whether on flanged or plain faced pulleys, had best be crossed for regularity of velocity and quantity of power to be imparted by them, as well as for durability.

Civil and Mechanical Engineering.

THE LOWELL AND LYNN COMPOUND PUMPING ENGINES.

MR. JAMES H. HARLOW.

With note by the Editor of the JOURNAL.

From the Transactions of the American Society of Civil Engineers. Extracted from discussion on papers before the Society at their seventh annual meeting in June, 1875. In the course of proceedings when the subject of pumping engines was under consideration, Mr. James H. Harlow, M. A. S. C. E., made the following statement:

The Lynn and Lowell engines are considered the best pumping engines in the country, because they gave the highest duty of any on special trial, viz.: 103,923,215 and 93,002,272 feet pounds respectively. A high duty in a special test is of no practical value to those using the engine, except to show whether the engine is a good or poor one. An engine that will not give a high duty on special trial will not be likely to give so good a duty on a yearly run.

The duty of an engine for *practical* purposes should be calculated on the *total* amount of coal used, without deduction of any kind whatever. The coal must be paid for, whether combustible or ashes. On a special test, I do not know why combustible is not as well as anything to calculate duty on; for in comparing two engines the amount of combustible should be taken into account. The point where these engines are to be beaten, if at all, is in their cost. If the interest on the extra cost of one engine over another, exceeds the cost of the saving in fuel, it will be cheaper to use the inferior engine. (This does not cover the whole question but is the main item.) The cost of the engine is understood to mean the cost of everything dependent on the style of engine.

In order to show what the Lynn and Lowell engines do, as they are usually run, I have prepared the accompanying table of work

done in May, 1875. The notes from which the table is compiled were taken by myself from the books of record kept by the respective engineers and are expressed in columns A, B, F, G, H and J; sufficient explanations are at heads of these columns. Column C gives the quotient resulting from dividing the number of revolutions by the minutes run. The rated capacity of each engine is 5,000,000 gallons per 24 hours, although each will do a little more. In order to pump 5,000,000 gallons in 24 hours the Lynn engine must make 18 6 and the Lowell engine 11·18 revolutions per minute. The average speed of the Lynn engine exceeds the above by 0·48 per cent.; the Lowell engine never came up to the speed above, the average being but 76·2 per cent. of 11·18 revolutions per minute. The reason for the low speed is, that the engine draws from a filter gallery that does not furnish a full supply for the engine. Column D, is the quotient of column J, divided by 5,000,000, the rated capacity of each engine. Column E shows the state of the pump-well. The pump-well of the Lynn engine is supplied with water through pipes, connecting with the ponds under a head of 20 to 25 feet, thus enabling the engineer to keep practically the same depth of water by opening or closing a gate at the engine house. The pump-well at Lowell receives its supply through a pipe connecting with the filter gallery, which in turn receives its supply by the infiltration of water through the gravel; thus it is out of the power of the engineer to prevent the variation in the well, which sometimes amounts to 12 feet. Column I is the total coal minus the ashes, divided by the total coal. Column J is the number of revolutions multiplied by the actual capacity of the pumps as determined by experts, viz. 186·7 and 310·4 gallons; the loss of action of Lynn pumps was 3·9564 per cent., and of Lowell pumps, 3·6497 per cent. Column K is duty by formula given at head of column, in which G = gallons, as given in column J; H = dynamic head, as given in column F, and W = weight of coal in pounds, as given in column G. Column L is a duty calculated on the assumption that the Lowell engine runs the same *length of time* as the Lynn and making a corresponding increase in amount of water pumped and coal used while running. The duty would then be calculated on the coal given for the Lowell engine, minus 960 pounds used for other purposes and increased by the same ratio as the times, between the Lowell and Lynn engines, plus 960 pounds.

At Lynn are two boilers (a more particular description of which may be seen in the report of experts* upon the trial of the engine,) both of which are generally in use. There is also a small boiler used for heating the building, but which was not in use in May. The boiler feed-pump is situated in the boiler-room, it is not connected with the engine, and takes steam from the main boiler. The experts† find that this feed-pump uses as much steam in 8 hours as would have been used in 52 hours, if connected as at Lowell. The jackets of the steam cylinder are supplied with steam from the main boiler.

It is the custom at Lynn to start with cold engine, boilers and water, to run several days at about 62 per cent. of the engine capacity and then to allow the fires to burn out, lie still a few days and start again. Before starting everything is cleaned up. The amount of coal allowed by the engineer was, in May 3900 pounds, or 355 pounds each time the fires were banked. There are also allowed 12,000 pounds for starting. This would give an average of 545 pounds each time the steam was raised after banking, and 1200 pounds each time steam was raised from cold water. This method of running would seem to be the most economical unless the deleterious effect of expansion and contraction (by reason of heating and cooling of the cylinder, which would add to the cost of repairs) would balance the saving in coal used. The force main is 20 inches in diameter and 1904 feet long.

At Lowell are three boilers of similar construction‡ to those at Lynn; one boiler was in use except when burning cinders, when two were used. A small boiler is used (in which steam is constantly maintained) for the steam-jackets; when the engine or main boilers are not in use 360 pounds of coal per day are required. During the time the engine is running, steam is supplied to the jacket from the main boiler, being shut off from the small boiler. The feed-pump is attached to the engine, takes water from the hot well and forces it through a heater 24·5 feet long and 2·5 feet in diameter, placed in the flue leading from the boiler to the chimney to the boiler. The engineer claims by this means, he utilizes 50° of heat that would otherwise be lost. There is

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*Lynn Water Works. Report on the Trial of Duty and Capacity of the Pumping Engine. December, 1873.

†Report, page 20.

‡ Mr. Harlow is mistaken as to the construction of these boilers. Those in use at Lowell are shown at the end of this article.

PERFORMANCE OF LYNN AND

For references see

DAY OF MONTH.	MINUTES RUN. A.		REVOLUTIONS B.		REVOLUTIONS PER MINUTE. C.		RATIO OF QUANTITY PUMPED TO CAPACITY. OF ENGINE. D.		DEPTH OF WATER IN WELL BELOW GUAGE. Feet. F. (*a*)	DYNAMIC HEAD PUMPED AGAINST. Feet. F. (*b*)
	Lynn.	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lowell.	Lowell.
1	....	360	....	2 867	....	7·96	....	0·178	20–28	163·75
2	....	300	....	2 766	....	9·22	....	0·171	20–26·5	163·
3	915	375	17 000	3 045	18·58	8·12	0·635	0·189	20–28	163·75
4	890	360	16 611	2 969	18·66	8·24	0·62	0·184	20–28	163·75
5	910	375	16 783	2 905	18·44	7·75	0·626	0·18	20–28	163·75
6	980	360	18 172	2 797	18·84	7·77	0·678	0·174	20–28	163·75
7	....	365	....	2 834	....	7·77	....	0·176	20–28	163·75
8	....	370	....	2 871	....	7·76	....	0·178	20–28	163·75
9	....	360	....	1 928	....	5·36	....	0·119	20 28	163·75
10	....	370	....	3 084	....	8·33	....	0·191	20–28	163·75
11	915	610	16 915	5 600	18·48	9·18	0·632	0·347	18–28	162 75
12	900	600	16 598	5 105	18·44	8·51	0·62	0·317	18–28	162·75
13	895	....	16 630	....	18·58	....	0·621	....	....	....
14	895	600	16 800	5 465	18·77	9·11	0·627	0·339	16–28	161·75
15	....	435	....	3 700	....	8·5	....	0·229	18–28	162 75
16	....	....	... .	....	....	....	....	....	....	....
17	....	575	....	5 229	....	9·09	....	0·325	16–27	161·25
18	....	455	....	3 646	....	8·01	....	0·224	19·4–27	163·45
19	....	445	....	3 895	....	8·75	....	0·242	18·9–27·6	163·5
20	905	465	16 810	4 081	18·57	8·77	0·627	0·253	19–27	162·75
21	890	450	16 463	3 812	18·50	8·47	0·614	0·237	19–25	161·75
22	940	545	17 488	4 395	18·61	8·06	0·653	0·275	19–26	162·25
23	....	....	....	....	....	....	....	......	....	....
24	....	615	....	5 537	....	9·	....	0·344	16·6–28	162·05
25	....	435	....	3 765	....	8·66	....	0·233	20–28	163·75
26	900	485	16 588	4 024	18·43	8·3	0·619	0·25	19–28	163·25
27	890	520	16 530	4 622	18·27	8·89	0·617	0·287	18–28	162·75
28	900	485	16 754	4 343	18·62	8·95	0·625	0·27	18–28	162·75
29	....	525	....	4 834	....	9·21	....	0·3	18–28	162·75
30	550	....	12 322	....	22·44	....	0·46	....	16·6–25	....
31	915	570	16 800	5 608	18·36	9·84	0·627	0·348	....	160·55
Total....	14 190	12 410	265 264	105 727	....	....	....	....	....	....
Average.	887	460	....	....	18·69	8·52	0·618	0·243	....	162·95

Lowell Engines, May, 1875.

foot note, page 310.

Total coal used. Pounds. G.		Ashes or non-combustible. Pounds. H.		Per cent. of combustible. I.		Gallons of water pumped. J.		Duty per 100 lbs. coal. $D = \frac{G \times H \times 8.34 \times 100}{W}$ K.		Duty at Lowell, under ass'mpn as stated. L. (*d*)
Lynn.	Lowell.	Lynn	Lowell.	Lynn	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lowell.
....	2 158	......	533	......	....	....	889 917	....	56 317 974	....
....	2 060	......	....	......	88·1	....	858 566	....	56 658 130	....
5 350	2 093	590	493	89·		3 173 900	945 168	80 771 604	61 672 014	84 551 270
4 850	1 960	600	212	87·6	89·2	3 101 274	921 577	87 062 640	64 213 194	90 632 042
4 850	2 060	570	....	88·3	89·8	3 133 386	901 712	87 961 245	59 778 792	82 367 547
4 100	2 060	730	423	82·2		3 392 712	868 189	112 663 260	57 556 580	81 604 423
19 150*c*	1 786	......	202	......	88·7	12 801 272*c*	879 673	91 013 042*c*	67 264 470	....
....	1 798	......	210	......	88·3	....	891 158	....	67 688 265	....
....	1 823	......	186	......	89·8	....	598 451	....	44 832 052	....
....	1 830	......	222	......	88·1	....	957 273	....	70 286 016	....
5 750	2 620	540	416	90·6	84·1	3 158 030	1 738 240	74 776 948	90 052 440	102 581 490
4 800	2 491	540	1 252	88·8	41·7	3 089 847	1 584 590	87 897 531	86 343 628	99 055 205
4 800	360	480	....	90·	....	3 104 821	....	88 067 265	....	....
4 300	2 600	720	1 137	83·3	56·3	3 136 560	1 696 336	99 313 545	88 013 640	100 165 704
19 650*c*	1 993	......	595	......	70·	12 498 258*c*	1 148 480	86 597 680*c*	77 217 364	....
....	360	......	....	......	....	....	....	....	....	....
....	2 703	......	480	......	82·3	....	1 623 081	....	80 753 208	....
....	2 509	......	303	......	87·2	....	1 131 718	....	61 487 817	....
....	2 360	......	207	......	91·3	....	1 209 008	....	69 855 597	....
5 250	2 360	527	....	89 9	86·2	3 138 427	1 266 742	81 390 222	72 855 542	90 729 480
4 850	2 162	510	623	89·5		3 073 642	1 183 245	86 284 120	73 829 400	94 584 130
4 300	2 460	900	293	79·1	88·1	3 265 010	1 364 208	103 379 720	75 040 707	89 692 600
14 400*c*	360	......	....	......	....	9 477 079*c*	....	89 604 123*c*	....	....
....	2 560	......	695	......	72·9	....	1 718 685	....	90 734 000	....
....	2 260	......	....	......	88·6	....	1 168 656	....	70 619 656	....
5 650	2 360	490	528	91·4		3 096 980	1 249 049	74 629 328	72 058 767	88 751 146
4 800	2 560	570	837	88·2	67·3	3 086 151	1 434 669	87 537 700	76 067 500	90 095 480
4 800	2 560	480	417	90·	83·8	3 127 972	1 348 067	88 723 960	71 475 883	86 502 714
15 250*c*	2 560	......	225	......	91·2	9 311 103*c*	1 500 473	83 128 642*c*	79 556 273	....
4 100	360	580	....	85·9	....	2 300 517	....	76 394 260	....	....
4 800	2 662	620	....	87·1	....	3 136 560	1 740 723	88 967 550	87 558 280	99 393 182
77 350	62 878	9 447	10 489	......	....	49 524 787	32 817 661	....	....	....
4 834	2 329	590	403	87·8	83·3	3 095 299	1 215 469	87 179 660	70 924 279	89 752 920

no banking of fires under the main boiler, the fire being started new each morning from water at about 212° (as the engineer informs me.) The engine is run until it will run no more, reducing the steam to about 17 pounds pressure. The fires are allowed to remain until morning, when they are dumped and new started. The engineer allows 600 pounds of coal for raising steam, being, with 360 given above, 960 pounds used for other purposes than making steam when running. This engine is compelled to run each day, as its supply is drawn from the filter gallery, which will not furnish enough to run at maximum speed for a few days and then allow fires to burn out and rest awhile. The force-main is 24 inches in diameter and 2,666 feet long. If at Lowell there was used as good coal as at Lynn, the engine would give 4·5 per cent. better duty.* The following is deduced from the Table :—

			Column K.		Column L.
	Lynn.	Lowell	Lynn.	Lowell.	Lowell.
Duty on average combustible............	4 244	1 926	99 299 350	85 764 608	107 739 900
" " coal used while running................	....	....	107 230 881	102 960 604	....
" " combustible used while running.	....	....	122 130 844	123 362 070	....

At the conclusion of Mr. Harlow's remarks, Mr. E. D. Leavitt said (referring to the report of the Committee on Pumping Engines, which was under discussion when Mr. Harlow presented his statement) :

The superiority of beam-engines in respect to low cost for repairs is very clearly shown by the returns from Chicago, Louisville and Cleveland—this item, in many cases, ranks second to fuel only—and it is worthy of remark that at Chicago, with a duty of only 44,750,000 feet pounds; and coal at $8.56 per ton, water was delivered for 9·671 cents—while at Salem, with a duty of 59,000,000 feet pounds, and coal at $7.14 per ton, it cost 12·156 cents—per million gallons raised one foot high.

*References made in the table :

(*a.*)—Depth of water in well below guage—Lynn 20 feet, with but little variation.

(*b.*)—Water guage, each day run,—Lynn 62, and Lowell 60·5 pounds. Dynamic head pumped against—Lynn 163·25 feet.

(*c.*)—Total or average for this run.

(*d.*)—At Lynn two boilers were used when running, and at Lowell from May 11th to 18th and from May 25th to 31st; the remainder of the time at Lowell but one was used.

Comments by the Editor of the FRANKLIN INSTITUTE JOURNAL:

This very full and at the same time succinct statement and comparison of these rival engines is a highly acceptable addition to our American Engineering reports, and forms a supplement to the previous reports to the society, which have been published in its proceedings from time to time.

A preliminary remark which was made at the same meeting by Mr. David M. Green, M. A. S. C. E., coincides so entirely with the opinion of the writer that he thinks it well to corroborate it by an example. Mr. Green said: "*The necessary elements relating to any pumping engine and its appurtenances being given, it is quite practicable to determine in advance what will be the character of the performance of that engine.*"

The Lowell engine with boilers and appurtenances was built to specifications prepared by the writer of these comments, who controlled by stipulations as to performance and capacity, and constrained by some details of construction given in the advertisement for proposals, determined the proportionate dimensions, as also the specific mechanical construction of the several parts. The whole was built and completed under his direction, the work having been performed at the Southwark Foundry in this city, of which establishment he was superintendent.

The engine is a compound one of the rotative (Simpson) type, and was intended to follow established practice as to dimension, and in every particular detail, with the least of novelty or deviation, only allowing some adaptation of arrangements which had the warrant of years of use in England.

In weight of parts, and of the whole, and in general construction, it is thought to approach more nearly to a "Simpson" engine than any other in America.

There were some demands in the advertisement for proposals which were likely to be injurious to engine or boilers, and which were finally insisted upon by the Water Commissioners, such as a very dubious patent piston packing, no doubt very satisfactory to the patentee, but not so certain to a builder under penalty, or to a user for years of continuous service—a patent grate without dubiety, as the writer is confident that it occasions 3 to 7 per cent. of loss—a requirement for clustered metal water valves, of area referred to the area of the pump regardless of its capacity and stroke. This arrangement is wasteful

in wear, and invariably noisy, and the excess of dimension for the short stroke pump aggravated the difficulty, the whole being greatly inferior to the single three or four beat valve, of proper size for the work.

The engine was planned not for 5,000,000 gals. (24 hours) capacity as a maximum, but as a mean. It was intended to run from 8 to 14 revolutions per minute, and to pump the 5,000,000 gals. with 11½ revolutions, allowing 5 per cent. to be wasted in the pump and its valves.

The weight of fly-wheel had been specified, but was decidedly too low for ease of motion at the centres, and almost for passing them, if the speed was less than 10 revolutions per minute, *when the steam should be cut off at such a point as would give one hundred millions duty.*

The principal modifications of engine in the way of novelty, were a peculiar arrangement of joints in the parallel motion, whereby the radius bars and parallel bars were all single rods, a special cross-over casting for transferring the steam from small to large cylinders, and the attempt to regulate the engine automatically against variation of steam pressure in the boilers, by the German cut-off lifting cam actuated by a governor. The entire engine, with its independent bed-plate, horned beam, short stroke main pump, side pipe disposition, and general architectural effect was peculiar, but from an engineer's (not patentee's) stand point, not novel.

The boilers were of a style designed by the late Jos. Nason and the writer, for use at the Capitol in Washington, in 1856, and had had the sanction of 14 years' service, with average of nearly 12 pounds of water evaporated per lb. of anthracite coal consumed.*

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* A report of two boilers at the U. S. Capitol, south wing, week ending Dec. 31st, 1859, showed six days, 92 hours' firing (the remainder of the time banked), all coal, used 53,165 lbs. ashes and clinkers weighed out 7300 lbs. Water evaporated by (tested) Worthington meter, 8448 cubic ft. (est. at 62½ lbs.) = 528,000 lbs. 62 square feet of grate were in use. The feed-water was heated by return steam from coils to 160°. There was burned, per square foot of grate por hour 9·3 lbs. coal or 8 lbs. of combustible (this quantity was probably overstated 10 per cent. as the banking coal was estimated as consumed in the hours of active firing).

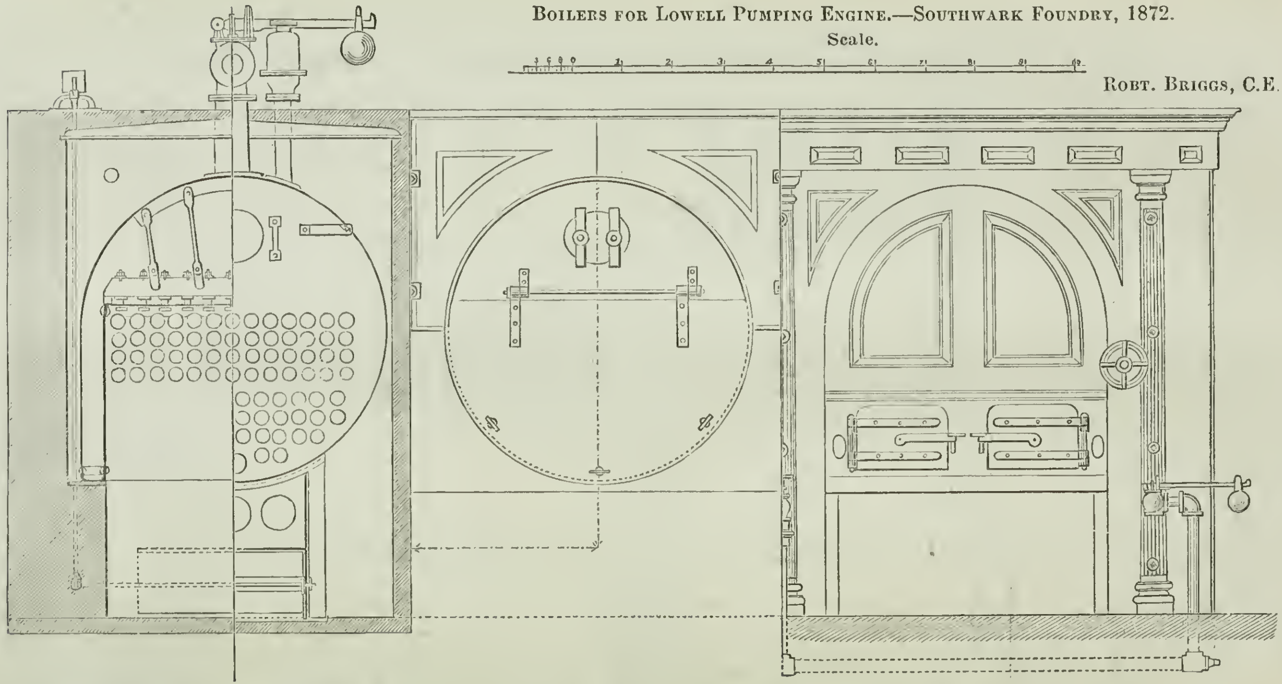
The evaporation was	9·93 of water from 160° to steam (of 30 lbs. or) 259° to 1 of coal.	
	11·29 " " " 160° " " " " " 259° to 1 of comb'stible	
Equivalent to	10·60 of water " 212° " " @ 212° to 1 of coal.	
	12·04 " " " 212° " " " 212° " 1 of combustible.	

The weekly reports throughout the season 1859–60, averaged to correspond with this one.

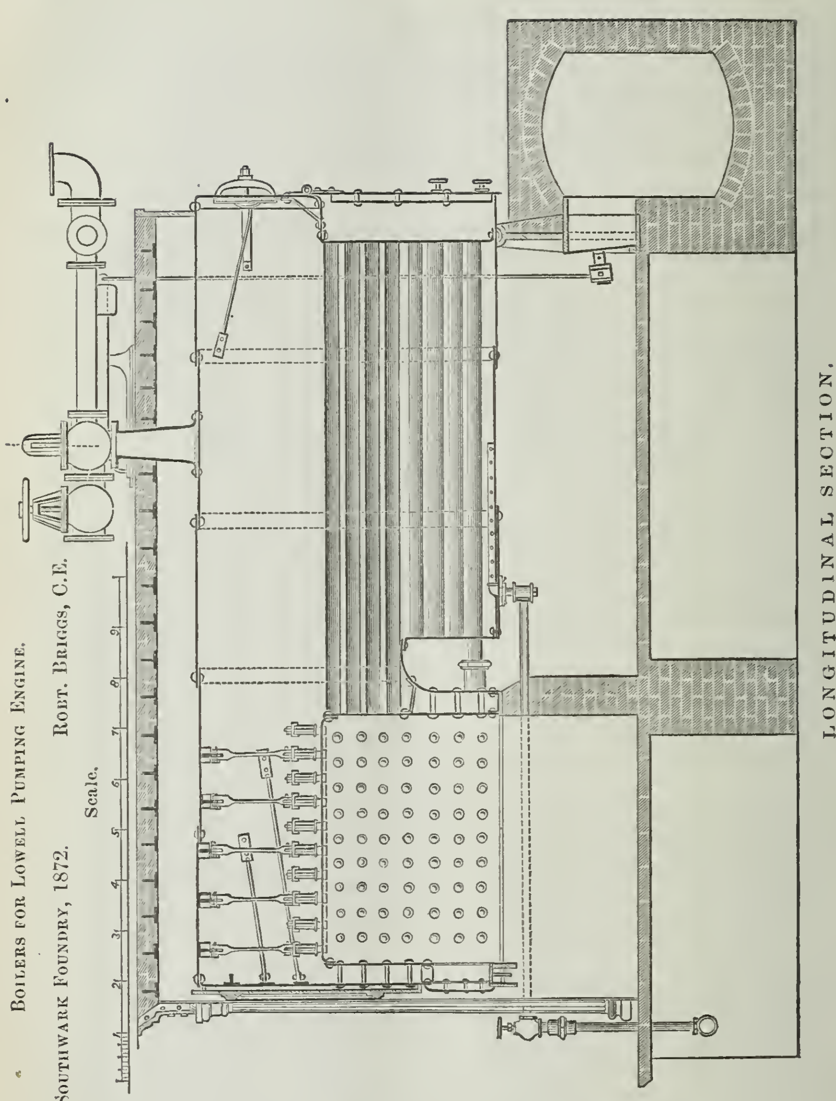
BOILERS FOR LOWELL PUMPING ENGINE.—SOUTHWARK FOUNDRY, 1872.

Scale.

ROBT. BRIGGS, C.E.



Section through Fire-Box.　Section through Waist of Boiler.　Elevation of Back.　Elevation of Front.



PROPORTIONS OF BOILERS FOR LOWELL PUMPING ENGINE:

Fire box surface, ...	86·0 sq. ft.
Down take surface, ...	14·1 "
Gap surface, ...	18·1 "
Shell surface, (not est.)	
	118·2 sq. ft.
52 upper tubes, $3\frac{1}{2}$ in. dia.	
51 lower " $3\frac{1}{2}$ in. dia.	
surface,	759·3 "
	877·5 sq. ft.

Grate surface, 5 ft. × 5 ft. = 25·00 sq. ft.

Area of tubes (or flue section) = 3·47 "

Ratio of heating surface to grate = 35·1 to 1.

Ratio of flue section to grate = 0·139 to 1 :: 1 : 7 (nearly).

With this somewhat long premise, the remark of Mr. Green can be recurred to: it is quite practicable, to determine in advance what will be the *performance of an engine.* The Lowell engine was based on the following figures :

English experience has obtained 100 millions of duty (English millions, which exceed ours in the ratio of 112 to 100), with 60 to 80 lbs. of steam pressure, when the capacities of the high and low pressure cylinders bear the ratio of one to four, and by cutting off in the high pressure cylinder at one-third to one-fourth the stroke.

The exactness of these figures as data need not be questioned. It is evidently sufficient to admit or assume they have been reached under conditions of good construction, in most, if not all regards.

The requirement at Lowell is to pump 5,000,000 gals. (U. S. gallons of $8\frac{1}{3}$ lbs. each), under a head of 157 feet from level of sluice way to that of reservoir, through a 24-inch main of about twenty-five hundred feet length. The resistance of this main, calculated by Weisbach's formulæ, is very nearly 3 feet additional head. Giving a total head of 160 feet. [$160\frac{1}{2}$ to $163\frac{1}{2}$, table F, the limited supply from the filter galleries keeps down the level in the sluice way.]

$\therefore \frac{5,000,000}{24 \text{ (hours.)}} = 208,333 : \frac{208,333}{60 \text{ (minutes.)}} = 3472$ gals. per minute $\times$ 8·34 lbs. = 28,956 lbs. $\frac{28,956}{62{\cdot}4 \text{ (lbs. per cubic ft.)}} = 464$ cubic feet, add 5 per cent. (for leakage† of pump piston, and at valves) = 487·2 cubic feet per minute.

Suppose the pump to be three feet in diameter and six feet stroke, its cubic capacity will be 42·41 feet. $\therefore \frac{48{\cdot}72}{42{\cdot}41} = 11\frac{1}{2}$ strokes (double) per minute. $11\frac{1}{2}$ strokes $\times$ ($2 \times 6' =$) 12 feet of stroke gives 140 (nearly) feet per minute as the speed of pump piston, evidently not too high a rate.

28,956 lbs. per minute is the net quantity pumped $\div$ 23 single strokes = 1257 lbs. to be pumped; each single stroke $\times$ 160 feet = 205,910 ft. lbs. $\div$ 1,000,000 (American millions are here taken as sufficiently accurate for this purpose) gives 0·206 lbs. of coal burned

† This allowance of 5 per cent. is shown to be correct by the Berlin example and thers, of which there are numerous reports.

for each single stroke, when the duty is attained. This coal *must generate* the steam to supply the cylinders.

Suppose the boilers to be capable of evaporating from and at 212°, eleven lbs. of water to a pound of coal burned. [A high, but not excessive rate of evaporation for boilers, used with pumping engines. The assumption of 100 millions duty demands excellence on all points.] $\therefore$ 0·206 lbs. coal $\times$ 966·1 units of heat per lb. $\times$ 11 = 2189 units of heat per stroke.

Two values of pressure of steam were assumed, 60 and 80 lbs. (above the atmosphere) per square inch, The feed-water in either case can be taken at 60°. The temperature of steam at 60 lbs. = 307°, and that at 80 lbs. = 324°. Rankine's formula $h = 1114° + 0{\cdot}305\ T_1 - T_2$ for total heat of evaporation from water at T_2 to steam at T_1, gives

For 60 lbs. = 1146 units $\therefore \frac{2189}{1146} = 1{\cdot}91$ lbs. steam $\times$ 5·8 cubic ft. (per Rankine's tables) = 11·078 cubic ft. steam.

For 80 lbs. = 1153 units $\therefore \frac{2189}{1153} = 1{\cdot}90$ lbs. steam $\times$ 4·55 cubic ft. (per Rankine's tables) = 8·645 cubic ft. steam.

The relative assumptions for points of cut-off, were

For 60 lbs. = one-third the stroke $\therefore$ 3 $\times$ 11·078 = 33·234 cubic ft. capacity of cylinder.

For 80 lbs. = one-fourth the stroke $\therefore$ 4 $\times$ 8·645 = 33·580 cubic ft. capacity of cylinder.

The high pressure steam cylinder for Lowell was assumed at three feet diameter = 7·068 feet area; it was also taken at five feet $1\frac{5}{8}$ inches stroke, whence its cubic capacity was 36·297 feet, about 8 per cent. in excess of the actual dimensions given by the estimate. This excess was purposely allowed to ensure the result. There was a question whether upon the 5 per cent. of leakage there was not as much work (*i. e.*, coal) expended (or at least a portion of the work) as upon the water actually lifted, and the passage loss of steam is 1 to 3 per cent.

The high pressure cylinder being taken at 36·3 cubic ft., the low pressure one under the basic assumption becomes 36·3 $\times$ 4 = 145·2 cubic ft., and if the stroke comes conveniently at 8 ft., the diameter becomes 4·8 feet. In the Lowell example, the low pressure cylinder was made 4 ft. 9 in. diameter by 8 ft. stroke.

The coal has been found to be 0·206 lbs. per single stroke × 23 = 4·738 lbs. per minute × 60 = 284·28 lbs. per hour. [The boilers ought to be run on anthracite coal, at not less than 8 lbs. of coal per square foot of grate per hour; if pushed faster, proportioned as the heating surface in the Lowell boiler is, the gases of combustion will be overheated. The loss from this source, however, is not over 10 per cent. when the boilers are pushed over 12 lbs. of coal per square foot of grate per hour. Below 8 lbs. combustion, the coal begins to distill carbonic oxide gas, which is so intermixed with air and cooled down, as not to burn over the fire.] This requirement gave 35 square ft. of grate as the proper quantity to provide. The demands of the proposals were three boilers, of twenty-five square feet of grate each, which were furnished.

Two plates of elevations and sections of the boilers used at Lowell are given at the end of this article.

The actual quantity of coal fired (not consumed), as per table, columns A and G, was 5 lbs. per minute, with a duty of 71 millions, running an average of 7 hours, 40 minutes out of 24, and dropping the steam to 17 lbs. each day before stopping. At this last pressure, it can be shown that the engine cannot be performing at the rate of over 40 millions.

It can be safely asserted, that the Lowell engine *will* average for any length of time, 100 millions duty when it is run 23 hours out of 24, when the speed exceeds 11 revolutions per minute, and when the steam is kept at not less than 60 lbs., and is not throttled, but cut off in the high pressure cylinder, and until these conditions are complied with, it cannot be expected to come up to the estimated performance.

The engine was guaranteed for 75 (American) millions test duty.

The figures above given, are not made to suit the Lowell example, but the Lowell engine was proportioned from them. They are now transcribed from the original memoranda of estimate, unaltered, and are confidently offered to sustain Mr. Green's assertion, that "the performance of any engine may be stated in advance."

This system of computation can be extended to any order of engine, and the writer has used it with much satisfaction for computing dimensions of the intermediate-steam-chamber compound engine, with and without equality of work from the two cylinders, as well in the Woolf combination, which Simpson has adopted (and which the Lowell follows).

It is possible, of course, to calculate the performance of an engine more accurately and with fewer assumptions, but the method here exhibited is recommended for its facility of application, and is practically sufficient. It is based on actual results, and is divested of embarrassing conditions of pressures, expansions, condensation, balance of resistances, and all other theoretical considerations.

The proportions of the parts of the engine, fly wheel, air pump, force pump, pipe passages, valves, etc., the strength, thickness and weight of the several pieces, all demand computation by the mechanic, and ought to be as accurately determined as those for the capability of cylinders and other data pertaining to performance and result, should be by the engineer. It is difficult to say where the line of demarkation of the provinces of two kindred professions is to be made, but the figures given in this commentary are the primary ones, and will be found useful to both.

Having inspected the Lowell engine, at the completion of its erection; the writer was compelled, by the urgency of other business, to allow the testing trial to be carried on without his presence, and from that time until now, other avocations have prevented any, or but little consideration of its performance; and he wishes here to express his personal obligation to Mr. Harlow, for the excellent compilation and reduction of the records to readable form, as he has laid them before the Society of Civil Engineers.

The Mt. St. Gothard Tunnel is advancing with greater rapidity than has been made on any railway tunnel heretofore constructed. During the month of July the progress was as follows:—Length driven from north side, 113·40 meters; length from south side, 127·20 meters; total length driven during July, 240·60 meters. The position of these works on the 31st July was as follows:—North side (Goeschenen,) 2,330·90 meters; south side (Airolo,) 2,103·70 meters; total length driven, 4,434·60 meters; length remaining to be driven, 10,485·40 meters. Total length of tunnel, 14,920·00 meters. At this rate of progress, the entire work will have been completed by September 1st, 1878. It can scarcely be supposed that so great an undertaking will be carried to completion without accident, but with the usual allowances for engineering contingencies, it may be now assumed with safety, that the work will have been accomplished by the year 1880.

UNDER LONDON DOCKS.*

The difficulties that the East London Railway Company have had to encounter, and which they have now happily surmounted all but completely, have been of a more than ordinarily embarrassing and imposing character, and of more than one class, embracing, if we mistake not, obstructions legal and diplomatic, physical and financial. They are now getting to the light at the end of the vista; the heaviest of the works on the north bank of the Thames, including a passage under one of the basins of the London Docks, being now practically completed.

One of the heaviest works on the line—Brunel's famous Thames Tunnel, of 1300 ft. long,—was really opened, although not for railway purposes, on the 25th of March, 1843. In 1863 a select committee of the House of Lords on Metropolitan Railway communication reported in favor of the construction of the East London line, as part of an outer circle of railway communication within the Metropolitan District. In the year 1865 the company obtained their Act of Corporation for the construction of a line of about eight miles in all, to form a junction with the Great Eastern Railway at or near Shoreditch to pass thence, principally in tunnel, under the docks at Wapping, and through the Thames Tunnel to Rotherhithe, thence to junctions with the London and Brighton and the South-Eastern railways at their respective stations at Newcross. In December, 1869, the line was opened from the north end of the Thames Tunnel at Wapping to a junction with the Brighton line at Newcross. Other junctions with the lines on the south side are almost complete, and, as already stated, the heavy works between the Wapping shaft and the junction with the Great Eastern are in a very advanced state.

The curves and gradients are favorable, the quickest of the one being on a radius of fifteen chains, and the sharpest of the other a short length of one in sixty. The road is level under the docks, and then rises for a short length to Shadwell Station. The rails are to be double-headed, and of steel, weighing 75 lbs. to the yard.

As may be readily supposed, the heavy works on the north side commenced from the Wapping shaft. These are completed, including the covered way under the dock basin, excepting only a short connection that remains to be excavated to connect the portions of finished

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* From *The Builder*, London, September 18th, 1875.

way; which are of pretty much the same character as the works of the Thames Tunnel, separate "up" and "down" lines, with a 4 ft. 6 in. wall between. The arches are of the ordinary horseshoe shape built with seven rings of brick, and are surrounded with 3 ft. of puddled clay. They have also inverts of brick or concrete. The height of the arches from the rail level to the crown of the arch is 20 ft. and the greatest width 25 ft. In the deep excavations at Wapping 20 ft. of made ground had to be taken up, then 18 feet of gravel, before the London clay was reached. This contained numerous quicksand and pot holes that caused the engineer much trouble.

The property required for the railway between the river and the dock basin was of an inferior character, and a good deal of it was swept away to the improvement of the locality. The most important work here was the underpinning of the workhouse of St. George's-in-the-East. The other important works in underpinning are of one of the London Dock warehouses, and of the piers under it, of the groined arches forming the rum vaults, which were carried down to the level of the railway foundations. Further on the foundations of the Blackwall Railway viaduct were carried down to the London clay, to 50 ft. below the original depth. The preliminary underpinning operations delayed the execution of the other works; but all that remains unfinished now is in active progress. Proceeding northwards from Shadwell station, of which two-thirds of the station works are done, the covered way is nearly all completed to about 50 ft. north of Commercial-road. Between this point and Whitechapel-road the contractors are working at six different points in a short distance of 700 yards.

The retaining walls for the Whitechapel station are nearly completed, and scarcely anything remains to be done but the station. There will be a goods station here on the north side of the main thoroughfare, where the rail level is as near the surface as it can be without altering the levels of important thoroughfares. There will be a goods station at Shadwell also. Between Whitechapel station and the junction with the Great Eastern Railway at Brick-lane, the navvies are at work at five different points. The works here are comparatively light, and there will be no difficulty in completing them within the same time as the works between Wapping and Whitechapel will occupy.

The most interesting engineering exploit on the section is the covered way under the London Dock eastern basin. Operations were carried on, in the first instance, from the surface, and consisted in

dredging trenches in the bottom of the dock until the London clay was reached. The next process was the driving of the piles, clean-squared, and driven as closely jointed as possible. These are of about 14 in. on the side, and about a minimum of 40 ft. long. Fourteen steam pile-drivers were employed in sending them home. There are two rows of coupled piles outwards towards the dock, and one row on the inside towards the railway works. These placed at 4 ft. 6 in. apart inside, and the clay-puddle hard-rammed between the two wooden walls, are the coffer-dams for the protection of the workmen in constructing the covered way under the dock basin.

In addition to the pine forest laid under contribution to provide the piles, another and larger must have been felled and cleared to provide the enormous quantity of timber used in the internal timbering and staging fixed longitudinally, laterally, and with upright supports at the intersections, the spaces between at very short distances. Some idea of the resistant powers that had to be provided in the construction of the works, as well as for their enduring power, may be formed from the statement that the ordinary depth of water in the dock is 21 ft.; under this is a bed of 3 ft. of clay-puddle, followed by 4 ft. 6 in. of brick-work, being the crown of the arch, under which is the covered way, of about 15 ft. clear headway under the dock. In one part of the basin the water communication between one side and the other, and over the railway, has been restored, and one day recently the curious sight presented itself of several large merchant ships,—the *Raby Castle* and the *Victoria*, of London, among others,—lying berthed immediately over the railway, and the large first-class clipper *Lady Macdonald*, outward bound, crossing over it at right angles.

In the construction of these exceptionally heavy works at such low levels, of 50 ft. to 60 ft. below Trinity datum line, powerful mechanical appliances have been necessary, that have included twelve pumping-engines, working night and day; three of these, of 56-horse power nominal, employed at the London Docks, are equal to lifting 50 ft., 8,000 gallons per minute. The whole of the water pumped is from the Thames, or from springs, not a drop percolating from the docks through the finished works. A large number of powerful steam cranes have also been employed for lifting the excavated earth from the workings. Recently a million of bricks have been used, and 600 tons of Portland cement per week, besides a large quantity of blue lias lime. The large quantity of puddled-clay required for the works has been

brought to the ground in barges, much of it from the neighborhood of Rochester. The London clay is totally unsuited for puddling.

The engineering works of the East London line have been designed by Sir John Hawkshaw, as engineer-in-chief, Mr. W. Hunt superintending the execution of the works as resident engineer. The most serious mishap that has occurred since the works were commenced was in connection with the first dock coffer-dam. Delay in finishing the line, and the loss of human life and of money, would have been prevented, it is believed, if the plans for these works of Sir John Hawkshaw had not been unwisely interfered with. Mr. Thomas is the contractor.

The completion of the East London Railway will supply the missing link in the connection between railways separated by the Thames, and must greatly facilitate intercourse between Middlesex and Essex, and Kent, Surrey, and Sussex; it will give a stimulus to building operations; it will afford the shortest and the only unbroken route for minerals and merchandise between the northern and southern counties and the southern shipping ports, saving in addition to the advantage of continuity, five miles in distance. It will have no opposition to encounter either from rival lines, steamboats, tramways, or omnibuses, to which other metropolitan lines have to submit. It will also command a larger proportion of through goods and passenger traffic than the lines referred to. It seems likely to secure a considerable traffic from the Foreign Cattle Market at Deptford, and of timber trade from the Commercial Docks, by a short branch running into these docks. It will also have a siding and station at the London Docks, from which merchandise may be carried to and from all parts of the United Kingdom without transhipment. It will furnish the shortest route to the densely-populous districts in the east of London for the Crystal Palace, Hastings, Eastbourne, Brighton, and good routes to Ramsgate. Margate, and Dover.

Costly although the East London line has been,—500,000*l.* per mile,—its cost is much lower than that of any other metropolitan lines, some of which have cost from 850,000*l.* to more than 1,000,000*l.* per mile. The average distance traveled by the passengers on these lines, such as the Metropolitan, the Metropolitan District, and the Charing-cross, is not more, probably, than a mile and a half, whereas on the East London line the average distance traveled is unlikely to be less than four miles. The East London will be worked by the Brighton Company under agreement.

THE PRESENT STATE OF THE CORNISH ENGINE.*

It is well known to engineers that the Cornish Engine in Cornwall itself has much retrograded in economy the past 30 years, and, the following remarks of the editor and correspondents of the *Mining Journal*, coming from witnesses thoroughly cognizant with the present condition of the engine, seem worthy of reproduction in America.

The editor of the *Journal* says (in the paper of the 18th):

A thoroughly practical method of arousing Cornish miners from that distressing lethargy which has done so much to add to the hardships resulting from the long period of depression, happily now nearly past, has been adopted by Mr. Basset, of Tehidy, who proposes a series of handsome prizes, to be awarded upon results actually produced, and who has himself contributed a large amount to the prize fund.

In conducting mechanical processes it is an admitted fact that results once obtained can be obtained again, whence it follows that inasmuch as with the engine at the United Mines a duty of 128,000,000 has been reached, that is to say every pound of coal consumed has been made to raise more than 1,140,000 lbs. weight 1 foot high, the average duty of Cornish engines during the first half of the present year was but 47,000,000, so that each pound of coal consumed has raised only 420,000 lbs. weight 1 foot high. To put the case in still more simple form, the Cornish engines during the first six months of 1875 did with the same consumption of coal less than one-third the work which was actually done with the United Mines engine half a century ago. But this is not all, the Cornish engines were doing 10 per cent. more work in 1870 than in 1875, and they were doing 45 per cent. more work in 1842 than in 1875. The retrogression has thus been as constant as it is alarming, and reflects the utmost possible discredit upon both Cornish mine managers and Cornish enginemen. It would appear that a class of writing managers have taken the place of the practical managers of former years, and that these writing managers have not followed the excellent example of the German and American by acquiring technical knowledge likely to be useful to them in their business. Yet that Cornishmen are not without the constitution and character which make good miners is shown by the high positions they attain in foreign countries, but the general aversion to progress which prevades the county seems to deprive

*Extracted from the *Mining Journal*, London, September 18th and 25th, 1875.

Cornwall of her best miners, and leave none but the incompetent and uneducated to manage Cornish mines. The prizes suggested by Mr. Basset will, it may be hoped, create a spirit of emulation which will be alike beneficial to the miners themselves and to the adventurers whose money is sunk in mines of the country.

These remarks have called forth the following reply (in the paper of the 28th) from an "*engineer*" at Redruth. Referring to the quotation by the editor, of the high duty reached by Taylor's engine, United Mines, in 1842, to show the apparent retrogression in the Cornish engine since that period, the writer proceeds :

This comparison is now become of frequent occurrence, but no notice whatever seems to be taken of the different conditions under which Cornish engines, as a rule, are now worked, and at that period were worked, or of the age of the engines from which the present average is taken.

A glance at the duty paper of the former period will show that the engine-shafts were then nearly all perpendicular (at the present day we have *one*, against *seventeen* in 1842,) and where more than an average duty was reached, the engines were moderately loaded so that the friction was reduced to a minimum, and enabled a high rate of expansion to be carried out. The very opposite is the case in the present day, owing to the system of mining pursued of late years—sinking the shafts on the irregular course of the lodes, for sufficient and probably satisfactory reasons—but at an increased consumption of coal, friction of necessity being considerably increased, and a high rate of expansion becoming impossible. Compare, for example, Taylor's in 1842, and Pelly's, Crenver and Abraham, in 1875. Taylor's had a perpendicular shaft 200 fms. deep, with a load of 12 lbs. per square inch, working five strokes per minute ; and a new machine (Pelly's) has only 164 fms. perpendicular, 125 fms. diagonal on the corse of the lode, loaded 25 lbs. per square inch, and is worked upwards of 20 strokes. The conditions are so dissimilar that no comparison can be drawn ; the friction of the latter is considerably increased, and a low rate of expansion can only be reached ; that there should be more than 50 per cent. difference in the duty under these circumstances cannot, therefore, be wondered at. But it must not be supposed that everything went smooth with Taylor's engine ; this high rate of expansion resulted in a serious breakage, and from that day to this such a rate of expansion has not been attempted, neither do I think it would now be recommended by any engineer.

This is not the only reason that brings down the average. The average of the present day is in three instances made up of engines at work in 1842—Botallack, Carn Brea, and East Pool: their average duty in 1842 was 58 mills, now 39, but their average lode has increased from 12 to 17 lbs. per square inch; they have 140 fms. additional flat-rods, and this after 33 years' additional wear and tear.

Taylor's engine was a new one, working under exceptionally favorable circumstances, but the average of the present day include, the above-named engines (one of them has been at work 53 years,) and others working under the conditions named.

Let those who condemn the Cornish engine recollect that the present average duty of Cornish engines includes amongst them one which has been at work continuously on one shaft upwards of *fifty* years.

We extract from another part of the same issue of the *Mining Journal*, the following weekly statement, which is that referred to by the "*engineer.*"

The number of pumping-engines reported for August is 16. They have consumed 1819 tons of coal, and lifted 9,100,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 46,600, 000 lbs., lifted 1 ft. high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty :—

Crenver and Wheal Abraham		—Sturt's 90 in. .	Millions 50·1
Ditto	ditto	—Pelly's 80 in. . .	52·7
Ditto	ditto	—Willyams' 70 in. .	55·6
Dolcoath—85 in.			55·5
West Basset—Thomas' 60 in			48·3
West Wheal Frances—58 in.			52·2

It must be admitted from the engineering-commercial point of view that the attainment of so high accomplishment, as was indicated between 1830 and 1845 in Cornwall, may have been effected at greater cost in other ways than what was saved in coal. Selected coal, no breize, extra attention, extra risks of breakage in short cutting off, slow running, which meant large engines at greater primary outlay and interest, all these are items of constant expense.

The profitable limit of performance was undoubtedly surpassed in the emulation. If however it can be shown by a new competition that the loss has even partly been the result of negligence, rather than by overestimation, a desirable result will have been reached.

With the best of engines and with 128 millions of duty (English standard,) there is yet left over nine-tenths of heat of the fuel to account for, but it is only by keeping all that has been gained, that improvement can be expected.

GAS WORKS ENGINEERING.

By Robert Briggs, Civil Engineer.

Holder and Tank for the Citizens' Gas Light Company, Buffalo, N. Y.

[Continued from Vol. lxx, page 252.]

The time in which the tank was to have been completed and possession given to the iron workmen having expired, the writer visited Buffalo early in the month of October, and then made the first and only inspection of the tank work. The lines of the ground and those for laying out the tank and its column piers had been given by a local engineer, Mr. Davies, who was indeed amply competent to have had charge of the construction under the specification, but no further duty than the setting out was devolved upon him by the company, the contractor having been permitted to work in his own way with little occasional supervision from some of the directors.

The ground proved to be a fill of ashes and rubbish of 10 to 12 feet depth, which had been made on a loose alluvial deposit of 5 to 6 feet, and then came 2 to 5 feet in places of compact alluvial, somewhat clayey, to natural surface of rock. The surface of this rock had at one time been the bed of the Lake (or rather of the entrance of Niagara River) and rapids must have existed here; the location of the works being about 800 or 900 feet from present shore of the lake. The rock bed was very irregular and eroded by former action of water and ice, and at some places three or four feet of rock were removed to give the proper depth at the side of the tank. Elsewhere, in the immediate vicinity where the rock had been uncovered, fissures had been found, and blasting the surface had discovered channels, which were supplied with water from the lake (the surface of which was 5 or 6 feet above the level of the bottom of the tank) but in this place, by great good fortune, no such supply of water was disclosed.

There were, however, several springs of no great moment which broke out through the foot of the cone of alluvium left in the centre of the tank.

The provisions specifying for under drainage of the bottom had been neglected, and about 70 to 100 square feet of the paved bottom had been lifted by the force of the springs.

It was said that the walls of the tank all around, had their foundations on the rock itself, having been carried about 2 to 5 feet at one side below the specified depth for the purpose.

The bank of earth had been improperly shored for the loose material, and extensive caves had ensued, involving the loss of the old retaining wall and the shed, which the additional specification required to be supported. This loss, however, was inconsiderable in amount.

Much delay had followed the caving, and also from the non-performance of some sub-contract for excavation, and the brick work was three weeks behind. Three weeks *after* November 30th at Buffalo, is a serious matter in outside iron work.

Considering the fact that the loose material was only about 15 feet deep, on the average (both fill and soil) it would have been as well to have dug to a slope of one to one at once, and straightened up the sides of the cut, back of the wall, and filled solid in a back trench thus made after completion of the wall.

There had been a loss of lines incident to the cave, the pier stakes having been unprotected, and a second setting out by the surveyor had been made to correct the shifted piers. The back filling properly had been entirely neglected, and after the *rubbish* had been deposited 10 or 12 feet high, it was *puddled* by running in a stream of water by a hose. No iron ties were used, the contractor not deeming them necessary. Perhaps the most radical departure from good tank construction laid in leaving a cart-way gap at one place, which was not filled up until after the wall was to its height generally. Nothing but the rock foundation of the wall and the looseness of the back fill saved the tank in good shape against such defects in erection.

The bricks were very good, sound, straight, and hard burnt, but the mortar was made from a species of hydraulic lime, which had little or no quality of *setting*, and only hardened under water in time. It was said to become solid in two or three years, at the end of which time it had the character of our American natural cement of no very high grade.

This condition of the work becoming known to the writer, he at once called the attention of the officers of the company to it, and immediate steps were taken by them, to at least ameliorate, some of the errors. Many of the defects were beyond correction, but much was done to bring the work more nearly to conform to the requirements

of the specification. In one regard, attention is called to what was done: the bottom of the tank was cut through in channels from boiling spring to boiling spring (about 6 or 7 places existed when the water boiled an inch or two high amongst the bricks) and under drains formed to lead to a well at the edge of the bottom. This well, as specified, had a closure or diaphragm plate, one foot from the top, with a valve opening upwards in the middle. The drains *discharged under the plate*, and when the head of the water was strong enough, it lifted the valve. This it did without bursting up the bottom.

It follows from this system of drainage that all the springs can, with much freedom, enter the tank as long as the head of the water within the tank does not close the valve, but when the head of water within the tank is great enough to close the valve, no water can run out of it. To make this proposition more clearly comprehended, let it be supposed that the springs in the bottom of a twenty feet deep tank would find their level and fill it three feet in depth with water; now these springs must evidently have an overflow somewhere (in this case they had the lake 800 feet distant) and any attempt to fill in water above the level would result in its discharging at the the overflow of the springs. The water of the tank would thus empty to a certain level, through the same passages that previously had supplied it.

This description has been made so particular in order to convey the idea of what should be avoided in building a tank. With 25 years' experience in construction of gas works, the writer does not think that one tank out of three which he has had to do with has proved satisfactory. It is with great difficulty that a local house bricklayer can be induced to do hydraulic work. The few men who know how, and have done, government or dock work are so under-bid by those who contract to build, that their opportunities for employment by a gas company are very small. There are three things needed for a tight tank for a gas holder: a good specification, a competent engineer, and a number of skilled bricklayers. The willingness to pay for good work on the part of the gas company, and the honesty of the contractor, are conditions precedent to the construction.

At about four o'clock on Sunday afternoon, December 4th, a telegram was handed to me informing me that the holder had collapsed, and asking an immediate personal visit to Buffalo. At seven P. M. I was on the train for Buffalo, reaching that place at two P. M. on Monday.

An immediate examination of the wreck disclosed the holder with both sections down upon the anchor blocks, and the crown of the inner section introverted on three-quarters of the circle with the centre down some two and a half feet. The sheets appeared unhurt, but wrinkled, folded and buckled, the whole resembling the top view of a demolished umbrella. The man-hole plate was removed, and the water level was about four feet below the curb. A stream of water was leaking out of one of the bank walls and a small steam pump was also removing the water from the tank. And the thermometer was about 20° above zero, with a west wind that cut like a knife. A gang of men were removing the retaining wall at the piers on Georgia street.

An enquiry into the accident revealed that the tank had been filled with water some days, and the holder had been tested on Friday. It had proved excellently, had been blown out twice or more to work out the air, and the inner section had been elevated nearly or quite to full height. (It is not recollected if the outer section had cupped.) As the holder capacity was much needed it had been put into regular work by the gas company. Meanwhile, on Saturday, a leakage was observed, which was found to proceed from a crack in the tank at a column foundation near Georgia Street. After its discovery, the crack rapidly opened, and it was decided to pump down the water five feet or so, (to the level of the streets outside) and a small pump was put on to remove the water. At this junction it was also decided to discharge the gas once more (as gas was making very fast at the benches) to eliminate the last trace of air from the holder. The inner section was blown off by loosening the man-hole plate, until it rested on the blocks, when the man-hole plate was replaced tightly. All this was done without consultation with the foreman of the iron work, who had left the holder 8 feet or more out and going up at four P. M. on Saturday. Having thus arranged the holder, the gas inlet and outlet had been allowed to remain cut off, with the leakage of the tank and the action of the pump (which continued running during the night) until at three to four A. M. on Sunday, when the crown collapsed with almost explosive violence. Residents of dwellings 600 to 800 feet distant felt the vibration and shock of the catastrophe.

From the rate of discharge of water from the tank, it is probable that 12″ to 18″ of water pressure was accumulated before the crown yielded and 180 to 270 tons pressure were distributed upon this crown.

The gas was thoroughly displaced when I reached the holder, the cold air outside had descended to the level of the water, and expelled the last trace by diffusion, and an internal inspection with lights was possible. An examination from a float exhibited 13 of the 16 main rafters broken in the middle of their length, at the scarfed joint, where the queen posts attach, the breakage being merely the *shearing off* of the scarf piece bolts, (4 $\frac{5}{8}$ bolts); the parting of all the main tie rods, either at the king post in the thread portion, or by shearing off the bolt at the gusset next the legs (two of the gussets were torn away from all their bolts); the upsetting, but not shearing off, of all the centre plate rafter bolts and the crippling and springing of many, in fact most of the flat purlins.

The most striking evidence of the force expended was shown at the centre pier. It was a pyramidal pier 3′ 6″ square at the top, and spreading $1\frac{1}{2}$ inches in 12 inches on all sides; not very soundly built, and with mortar scarcely stiffened in its set; but it was massive, and it was capped by a sound block of Medina stone 3′ 6″ square by about 8 inches thick. The stone would be called good building material anywhere. The stone was cracked to small pieces, and the brick pier below it demolished and also crushed, many of the bricks being broken in fragments as well as displaced. The fracture of the pier was diagonal, as the three tie rods (and rafters) which were uninjured, had dragged over the foot of the king post about 12 inches to one side.

It did not seem that any serious injury had been done to the internal iron work structure.

Finding so good appearance within, a new and close examination of the sheets of the crown on the outside were made. Original good iron, the accurate punching of a multiple punch (which punched sixty holes at once, together with accurate laying out of sheets), and the avoidance of any reaming or stretching of holes when riveting, had produced so good work that no breakage or injury was apparent. Not a seam showed signs of a crack or opening, and although the buckles were (some of them) two feet or more in depth, and very short, (five to eight feet between crests of the waves) no bent plate could be found. With all this, it is proper to assert that the appearance of the top of the crown to an engineer or practical mechanic, without close examination, was truly hopeless for restoration; and

some opinions of very positive character had been given the Gas Company previous to my arrival in the city.

The result of the examination in my own mind, was to advise the pumping out of the tank as quickly as possible, before a snowfall, then to be expected daily, should load the crown, and cause further injury. And after the emptying of the tank to the level of about one foot above the anchor-blocks, to enter the holder with a gang of men, have it closed, and blown up with air ; and when the crown should be reverted to its original place by the pressure to straighten and shore up the rafters one by one ; to block up the king post from the centre, and having thus replaced the crown, relieve it of the air pressure, and letting out the gang of men, then proceed at leisure to repair the sheared and broken bolts.

The proposition was at once accepted, but simple as the measure, and perfectly safe the method, it was found merely impossible to impress either upon the workmen. Divers who were practiced in hours of work in the water at the bottom of Lake Eric, objected to the *risk* in this immense reservoir of 130,000 cubic feet of air. Carpenters feared the pressure, although they were assured they might be exposed to greater difference any summer's day. Gas workmen could think of nothing but explosion. And after reasoning with several, the writer found the only alternative was to remain in Buffalo and lead himself.

An examination of the tank showed three cracks from the top of the wall downwards, caused by insufficient backing. Two of these cracks followed the line of junction of column piers, and the third was intermediate (about half-way) between the two piers. In accordance with the advice of the writer, the backing at this place was excavated, and the earth removed to the very bottom of the tank wall, and a revetment pier of 8 feet projection and 3 feet width, behind the wall at the base, with a batter of $1\frac{1}{2}$ to 12 towards the tank as it came up, was built. From this revetment pier, two wings of brickwork were built to abut the column piers at their groin with the tank wall. From much experience, it can be said that the attempt to make a tank wall tight by pointing or grouting a crack, is nearly always a failure, and that all efforts short of revetment piers are so nearly direct waste of money, that no engineer is justified in advising them. A further allusion to the tank will be found in the report on the subject to the company, hereinafter appended.

Of course, this work of reparation of the tank had to be done under temporary cover, and also, of course, strict regulation was had as to walking on the crown in its precarious state.

The means for supply of air for the proposed operation, at the works of Buffalo Gaslight Company, were singularly favorable. The company had been making a partial hydro-carbon gas from anthracite coal and super-heated steam by means of a generator of the type introduced into this country forty years since by Faber du faur, (which gas was afterwards carburetted by benzine vapor *fixed* in it by passage through low heated retorts.) The generator was supplied by air by a Blake air pump having a capacity of 500 to 600 cubic feet of air per minute, and it was convenient to take the air by a line of 3-inch wrought iron pipes to the holder; there was an opening on the delivery of the air pump available for this purpose.

If, however, it had happened, that no such supply of air were at hand, it would have been feasible by means of four to six ordinary smith's bellows and a line of soldered tin pipe to have air under suitable pressure at the rate of 60 to 90 cubic feet per minute with, of course, some disadvantage in time. For the engine pump would lift the holder one foot in ten minutes, while the suggested bellows would have taken an hour and a half for the same result.

The preliminaries of pipe line, and all other steps essential to the success of the scheme were effected in readiness.

It was late on Thursday afternoon before the water in the tank was low enough to expose sufficient part of the conical bottom to work upon. At this time, the water was 3½ to 4 feet deep at the sides.

There had been taken into the holder and deposited about the centre of the cone, during the day, thirty lengths of hemlock scantling, $3'' \times 6'' \times 22'$, with other joists and boards for scaffolding, together with a pile of blocking timber, tools, etc., and at about eight o'clock, after several callings of the roll, ten out of twelve men were found.

Some experiments demonstrated that conversation could not be carried on, and a set of signals had been arranged. The order of repetition of raps on the inside of crown, was made into a telegraphic communication between *the ins* and *the outs*. Of course, it had to be very simple, as the occasion did not demand an extensive code. The inside of the holder was illuminated by forty or fifty 4-inch candles, secured to the rods of the crown by bits of copper wire. After calling roll, everything being ready, the foreman of the

gas works volunteering to act as outside director, the gang of men descended into the abyss, and the man-hole was bolted down. A little delay ensued by one man's having gone home (near by) to inform his family of his undertaking, and by his declining to join in the risk after his return, and the missing men came to the holder, one joining, and the other, after listening a few moments at the man-hole, and hearing no sound, solemnly pronounced them "all dead," and went his own way, above ground, in fear!

The ladders having been displaced, and the men put in such position that the fall of rods or rafters might not hurt them (only one end of one rod fell down), the proper signal was given, and the pump was started. In about a minute, an evident noise of shaking sheet iron was heard; in five minutes the king post was free from its centre pier, and the resonance of sheets was like distant theatrical thunder. In ten minutes the whole crown was inflated, and in about twelve minutes the outside director signaled that the inner section was three inches afloat from the anchor-blocks, and that he had stopped the air pump, as agreed upon. On the inside, the centre pier was leveled off, and the king post blocked up and wedged, when, at the signal, the air plug was opened, the holder dropped upon the anchors, and the discharge of air stopped, thus thrusting up the centre, and removing part of the *apple* shape. (It was supposed, when this was done, that three inches would have been enough, but subsequently, it appeared that the holder should have been lifted about nine inches, and then dropped, to have effected the end entirely).

The thirteen broken-backed rafters, were then found to be depressed in their middles (half way from edge to centre) from 2 to 3½ feet (except one which was detached from its position, and dropped 5 or 6 feet.) The restoration was exceedingly easy; one by one they were quick-shored and spur-shored, by the 22 feet scantling and blocking, offering some resistance and squirming as they passed the toggel line. They were shored up to the apparent proper curve without any attempt at exactness. As the work proceeded, the king post was straightened up, and finally lifted off from its blocking. When this occurred, a signal was made, and the section was raised again, the shores being watched to see that they were not loosened, and four inches of blocking more inserted under the king post, when the section was, by signal, again anchored. After this, some of the rafters

had to be further shored up. The whole work of shoring up the thirteen rafters occupied four and a half hours.

The work had been done in the night in preference, so as to ensure the undisturbed attention of the external requirements. It was an intensely cold night outside, but a few degrees above zero, and the clear sky gave a radiation through the thin plates of the crown, yet within the holder it was about 40 degrees and only chilly, and at the last smoky from candle smoke, but otherwise not uncomfortable.

At two o'clock in the morning, the signal was given, the man-hole was loosened and removed, and the workmen emerged. The exterior of the crown showed that the gradual lifting of the rafters had again elevated the whole roof, leaving the king post still down about six inches, and of course the sheets were not free from buckles, and the apple shape was very evident. As had been indicated by appearances, the sheets and joints proved unhurt and tight, not a particle of leakage of air having accompanied the raising of the crown, nor did any subsequent defect in this respect develop itself.

Having thus placed the holder in condition to be repaired, the erection of a temporary scaffold near the sides, and the testing and replacing of the injured parts of the internal framing was easy. In fact, a complete restoration was made in less than a week afterwards, at a cost of not to exceed $300 for the iron work, and the holder was ready for use again by the 20th of December, and was in use on the completion of the tank repairs, shortly after. It would be impossible to find any signs of injury from this accident at this time.

After completion of the holder, some questions from the officers of the Buffalo Gaslight Company led to the following report, which is here inserted as a means of conveying some information upon strength of tanks not accessible in similar form elsewhere.

Philadelphia, January 29th, 1875.

J. M. Vought, Esq.,

Secretary Citizens' Gas Co., Buffalo,

My Dear Sir :—In accordance with your request that "I should write you in full upon the failure of your tank, and state whether the specifications were carried out, and if not, whether that was the cause of the failure." I make the following reply : Referring to the specifications : *The sides of the excavation must be carefully shored to pre-*

vent caving ; and in case of a slip, the entire mass of broken earth must be removed, and a new fill puddled and rammed in the back of the wall.

The banks were not properly shored—there was a slip—the earth was not replaced by puddling and ramming as prescribed. The prescription of the specification relative to springy bottom was conformed to and the bottom is consequently tight. "*The proper care was* not *taken in setting out* or preserving *the location of column foundations,*" and much additional stonework was needed in the retaining walls to remedy the difficulty.

"*There will be laid in each course of mortar on the flat, each ten courses of bricks,* 3 *or* 4 *strips of hoop iron,* $1\frac{1}{4}$ *ins.* $\times$ *No.* 20 $\times$ 8 *to* 10 *feet lengths, the ends overlapping about two feet, to make the bond of the wall.*" This requirement calls for 11 courses of hoop iron strips $1\frac{1}{4}'' \times$ No. 20, and $3\frac{1}{2}$ strips to each course; the total weight of iron called for was only 2100 lbs., and the least section of all the bands together at any vertical section of the tank wall would have been equal to 1·69 square inches of solid iron. As expressed in the specification, this iron was only "*to make the bond of the wall.*" It was not supposed to be strong enough to form a hoop and sustain the pressure of water independent of the strength of the wall as masonry, or of its support by earth backing.

The total pressure of water tending to burst the tank walls at any place was, say $93'\ 6''$ (or centre of wall) diameter multiplied by $22'\ 8''$ depth of water, multiplied by $\frac{1}{2}$ the depth of water, multiplied by the weight of a cubic foot of water (62·4 lbs.) = 750,000 lbs. (nearly.) Now the foundation of the wall was on solid rock, and the weight of brickwork alone was sufficient to warrant the assumption that no splitting would have occurred at the bottom. And the application of this force of 750,000 lbs. can be taken at the centre of pressure ($\frac{1}{3}$ the depth from the bottom) with the bottom practically unyielding. This assumption is equivalent to the application of 500,000 lbs. uniformly on the sides of the tank.

Hoop iron of No. 20 (·035 inches) thickness has the highest tensile strength allotted to wrought iron, it is hard rolled and nearly unyielding to the point of rupture, and can be fairly assumed at standing a tension of 60,000 lbs. per square inch of section, before rupture. Assuming *one-half* this tensile strength, the section of 1·69 square inches gives 50,000 lbs. as absolute strength of the hoops.

The adhesion of mortar to the surface of each hoop is quite equal to its assumed tensile strain. The weakest place in the hoop is, of course, the middle of its length, and it can be estimated as subjected to strain in opposite directions from that point. The sectional area of the hoop equals $1\frac{1}{4}'' \times \cdot035''$ or $\cdot04375$ square inches; multiplying this by 30,000 lbs. tensile strain, and the total tensile strain is found to be 1312 lbs. The surface of either half of a ten-foot strip is $2\frac{1}{2}'' \times 5'\ 0'' = 1\cdot04$ square feet, or equal to 1300 lbs. adhesion to each foot of surface of the hoop.

These figures show the strength of the hoop ties as specified to have been about one-tenth that needed, if they were to have been the sole reliance against this bursting strain on the walls. The specification requires "*that the mortar to be used for bricklaying, concrete or cementing, must be one part of new hydraulic cement, of approved quality, and two parts of sharp sand, and must be used as fast as made; any set mortar must be rejected and not tempered into new mortar.*"

The material used to make mortar was not cement at all, but was hydraulic lime; as to the conformity in preparation to the specification, I cannot testify; but from inspection of the crushed centre pier, and at other parts of the work, I can say, that the mortar is only a fair building mortar, suited to make joints of brick or stone work of buildings or piers where the usual disproportion of material as regards loads superimposed upon it, is followed. It did possess a great advantage over common lime for water work, in having a degree of insolubility, and possibly in the same course of time which is requisite for good quick lime mortar to become hard, in construction above ground, this hydraulic lime mortar may harden under water; but as a mortar to be used in *cistern or tank work*, having the quality of quick setting and of immediate *tensile* strength, it by no means satisfies the conditions of the contract.

Unless this deviation from the requirements of the specification was made with the full consent and *approval* of the Gas Company, or their Engineer, the contractor should be fully held for the consequences. Admitting that the walls of the tank were built of specified thicknesses, and with specified quality of bricks, which so far as my observation went, were the facts; their strength as masonry, on the supposition that Rosendale cement had been used, can now be properly

considered. As in the case of the hoop bands, the bottom can be taken as unyielding, and the mass of the walls adhering to it as capable of sustaining one-third of the bursting strain, leaving 500,000 lbs. tension as the total load at any vertical section of the tank walls to be resisted. The walls have very nearly 50 square feet of cross section, and the consequent tension per square foot of brick work is 10,000 lbs. = (70 lbs. per square inch.)

The rupture of a mass of brick work can be estimated (if perfectly sound and of uniform strength) in either of the two following ways:—

First, on a plane of rupture at the ends of half the bricks, and across (through) the other half. A square foot of cross section of brick work (of Buffalo size) is 3 courses wide by 5 courses high, the bricks are $7\frac{3}{4}$ inches long $\times$ $3\frac{3}{4}$ inches wide $\times$ 2 inches thick, thus,

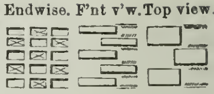
$7\frac{1}{2}$ ends to break, $3\frac{3}{4} \times 2 =$. $52\frac{1}{2}$ square inches.
$7\frac{1}{2}$ " " separate at the joint,
$3\frac{3}{4} \times 2 =$ . . $52\frac{1}{2}$ square inches.
Surface of mortar = . $39 = 144$ "

Bricks of low quality have, at least, 150 lbs. tensile strength per square inch, (all authorities give 150 to 300 lbs.) The adherence of Rosendale cement mortar to bricks after one month's setting is given by Gilmore to be, *at least*, 12 lbs. per square inch. The tenacity of Rosendale cement mortar laid out of water one month is deduced by Gilmore as fully equal to 50 lbs. per square inch [Grant. Inst. C.E., London, 1865, gives 100 for Portland average of 370 trials] and we have from above,

$7\frac{1}{2}$ ends to break $= 52\frac{1}{2}$ @ $150 = 7875$
$7\frac{1}{2}$ " " $= 52\frac{1}{2}$ @ $12 = 630$
Surface of mortar $= 39$ @ $50 = 1950 = 10{,}475$ lbs. per sq. ft.

For my own part I am decidedly of opinion that the 630 lbs. of adhesion of ends deducted from Gilmore's experiments are not over one-third the real strength (Gilmore's mode of test was very unfair), and I am confident that the least strength of a square foot of solid brick work in mortar of one part Rosendale cement to two of clear sand is quite 12,000 lbs. per square foot.

The second method of computing the rupture is to assume that it follows the joint, and does not part any of the bricks which have an average of 3 times the strength of the mortar.



In the top view, as the wall averaged but $3\frac{1}{2}$ bricks wide, there were but 6 joints for the 7 half bricks, or $2\frac{2}{7}$ joints to each foot of width. If the bricks were laid with perfect accuracy, they would have 4 in. laps, but it is fair to take the laps at not over 3 inches in practice, and thus is found:

15 ends of bricks to separate ($\times 3\frac{3}{4} \times 2$) =	105 sq. in.	@ 12 =	1260 lbs.
Surface of mortar on end section =	39 "	@ 50 =	1950 "
$5 \times 3'' \times 12''$ flat joints to break =	180 "	@ 50 =	9000 "
$2\frac{2}{7} \times 3 \times 12$ edge " " " =	82 "	@ 50 =	4100 "
			16,310 lbs.

Either of these computations show an excess of strength over the requirement, and that with the hoop iron to prevent check cracks and to strengthen the wall, where the header courses were used; the tank could have carried the weight of water without backing of earth. It was certainly amply strong *with* the required earth work or retaining walls to support it. But all this supposition rests upon "*Hydraulic cement of approved quality*," of which I should consider Rosendale as quite low as a standard. I do not believe the hydraulic lime mortar used, has at this time, a tensile strength of ten pounds per square inch.

"*Behind the walls of the tank there shall be filled in, rammed and puddled, suitable material to form a water-tight solid bank.*" I saw no ramming—the dumping of loose fill of rubbish into water by no means answered the requirement—the material used, to my view, was not suitable for filling, nor was any water-tight clay used. Considering the mortar employed and the omission of the hoop iron ties, the only reliance for the construction was the backing. If the backing had been properly done—according to the specification in all respects—it is my opinion that the defective brick work would have had adequate support, and no accident would have occurred. It is fair to admit, however, that while I consider the earth backing as equally imperfect with the brick masonry, the ruptures apparent at this time, have not happened when earth filling only was prescribed.

"*There shall be built on the line of the lot on Court Street and on Georgia Street, two retaining walls in stone masonry, each about 32 feet in length (exclusive of wings at either end, which may be needed to hold the bank.) . . . Below level of side-walk, these retaining*

walls are to have a footing on the natural ground (under soil) and at least 3 feet under side-walk level, which footing shall spread two inches in every foot of depth. These retaining walls shall be built up solid against the brick walls of the tank, ... at the end of the retaining walls will be required wing walls from 18 inches to 2 feet in thickness, with foundations at least 3 feet below side-walk level, suitably coped. The excavation for these walls will be made to such depth as may be directed by the Engineer of Gas Company," etc., etc.

The immediate cause of the failure of the tank laid in the non-conformity of one of these retaining walls (that on Georgia Street) with the specification as above quoted. [As to the other retaining wall, on Court Street, or the remainder on Georgia Street, I cannot say whether they were improperly constructed or not.] At the wall on Georgia Street, between two of the column piers, the tank wall went out with three cracks, one at each pier, and a third midway between; the cracks opening $\frac{1}{16}$ to $\frac{1}{8}$ inch at the top and extending about 12 feet downward.

The examination which followed, showed that the wall in place of having a footing spread two inches in width for each foot of depth below level of side-walk, which would have given 3 feet of external batter, had the foundation been carried down to the very bottom of the tank, was founded upon a triangular mass of concrete, which concrete had been substituted for the rammed earth specified to be used in case of a step. In consequence of neglect of the lines, the column foundations of the tank had been twisted about 8 or 10 feet out of proper position, and the retaining wall which should have been nearly parallel and of equal thickness, had become, say $3\frac{1}{2}$ to 4 feet wide at one column pier, and 8 to 10 feet wide at the next.

The triangular mass of stone work consequently overhung any foundation or footing at one place 5 or 6 feet, and in no one place had the wall what could be designated as a proper footing, leveled suitably on natural ground, or its specified substitute. On removal of the wall for reconstruction, it was found to have fallen away 2 to 3 inches in the widest places, with a pocket of 12 or 15 feet in length, where the wall had left the brick sides of the tank. This subsidence had evidently occurred whilst the wall was being built, and not afterwards; for the stone work had been gathered over against the tank wall. The retaining wall thus built, actually prevented the earth from sup-

porting the sides of the tank and became a point of weakness, instead of strength.

The wing walls were also improperly built; in place of being independent from the retaining walls, they were bonded into them and the foundations of these wing walls were also tied into the retaining walls. This bonding of walls, where footings do not coincide, is a serious injury to both; there should have been a plumb joint between the walls. I have enumerated the essential points of deviation by the builder of the tank from the specification, any one of which was fraught with danger to its stability, but the pre-eminent one is, "*These retaining walls shall be built up solid against the brick walls of the tank.*" With the use of inferior mortar and in the absence of the iron tie-bands, the accident was invited at this point and occurred *here.*

The specification reads: "*The Gas Company will hold the contractor responsible for the cost of reconstruction and for damages which may follow if the workmanship and material does not conform to this specification, whether noticed by the inspector or not; but will assume full responsibility for the tightness of the tank if the work is as specified.*"

The deviation from the specification in these regards named by me, I believe to have been one and all intentional by the contractor, with full knowledge and assumption of the risk, and they were done for the purpose of reducing (to himself) the cost of the work. In some of the deviations, he may possibly have had a color of permission or direction, but if so, I am confident such assent or authority was only granted on the assurance by the contractor that the changed construction or material was equally or sufficiently good.

The question of damages resulting to the Gas Company resolve themselves into several points.

First. The extra cost of stone work, incurred in buttresses because of twisting the column foundations after laying out by the Gas Company's Engineer. This is estimatable by your engineer.

Second.—A. The cost of repairing the break, including the pumping out and refilling of the tank, earth work, stone work or brick work, engineering, or other expenses. B.—The injury done to the holder, which was sucked in by the escape of water from the tank. C.—The loss to the company resulting from the supplying of the district by the Buffalo Gas Company.

Third.—A. The probable cost or equitable valuation of cost of reconstructing the next piece of retaining walls on Georgia Street, where another leak has already developed. B.—The probable cost of other reconstruction on Court Street side.

Fourth. The impaired value of the tank in its present state. This can be made up as follows: A.—The money value of material and workmanship improperly done. The saving on earth work; this value can be made up by your engineer. The saving in mortar and laying; this is also a matter of engineer's estimate for quantity; the saving of hoop iron (about one ton) and the cost of laying it, say one hundred dollars, ($100.) B.—The consequential injury; built as your tank has been, I should feel no security that it would remain tight from one week's end to another; by buttressing it, as the broken segment has been buttressed, at each of the eight spaces between columns, it could be made reliable. The cost of constructing this buttress thus becomes a measure of value of *reconstruction* to make the whole equivalent to its *specified* construction.

In settling this whole question, if the company feel any especial compassion towards the contractor, possibly they might authorize a settlement which would assume a part of the risk of future failure. It is clear now that one buttress more will be indispensable, how many others *may* be demanded, or their cost, taken as security against further accident could be determined by the Gas Company.

The view I have here given, will, I am confident, stand the test of legal scrutiny or of a settlement under an arbitration to engineers. The company had a right to receive as good a tank at the hands of the contractor as the specification described, and I cannot, in the circumstances, see any reason why they should suffer loss when the specification has been departed from. Respectfully yours,

Robert Briggs, C.E.

The Decimal System.—In "Money and Mechanism of Exchange," by Prof. W. Stanley Jevons, recently published in London, the decimal system is discussed at some length, with a conclusion that in the end it will predominate, but only from the hold which it has taken on the world; and accompanying the opinion that it is to be regretted, because "the duodecimal system is in various ways much more simple and convenient." This assumption of convenience as a fact and consequent reasoning that nothing but conformity is to be attained may be unanswerable in England, but it cannot be ever comprehended in America where the habit of using decimal money has incapacitated most people from the use or desire for any other.

Chemistry, Physics, Technology, etc.

THE EFFECT OF MAGNETIC AND GALVANIC FORCES UPON THE STRENGTH OF, AND DESTRUCTION OF IRON AND STEEL STRUCTURES.

By Charles M. Cresson, M.D.

(*Read before the American Philosophical Society, June* 18, 1875.)

Bars and Structures of Iron and Steel when allowed to remain at rest for a considerable time acquire measurable magnetic polarity.

Moderate percussion, alternations of heat and cold, exposure to the rays of the sun, especially with a long axis of figure parallel, or nearly coincident with a magnetic meridian of the earth have a tendency to develop and strengthen magnetic polarity.

Thus, Iron Bridges, Iron Vessels upon the stocks in progress of construction, and Iron Railway Tracks are particularly liable to acquire magnetic polarity.

It is asserted that the relative position of the long axis of Iron Ships with reference to the magnetic meridian materially affects their polarity and the facility of the correction of their compasses.

If the keels of such vessels be laid on a North and South line, they are supposed to acquire greater polarity, and to retain it more steadily than when laid East and West.

The evidence of an Iron Ship's polarity is exhibited to the greatest degree, by comparison of its effects upon its compasses when the vessel is sailing in an easterly or westerly direction.

A consideration of the following facts seems to favor the conclusion that magnetic bars of Iron should be better able to resist tensile strain than those which are not magnetic.

A thoroughly magnetic bar is one of which each end repels a pole of a magnetic needle. The centre of such a bar is neutral, that is attracts either end of a magnetic needle and repels neither.

If we break such a bar in half, we are possessed of two magnetic bars; that end of the original bar which attracted the south end of a magnetic needle continues to attract it, that which attracted the north end continues to do so, whilst the two new ends which had

formed the neutral centre of the original bar, each acquires a polarity opposite to the other, and also opposite to that possessed by its own opposite end. A continuance of this process, that is, the fracturing of each half until we have obtained such minute fragments of the bar as can be examined only under the microscope, still produces perfectly polarized bars, possessing all of the magnetic characteristics of the original bar, with varying, attracting, and repelling force according to some ratio of the relative length and thickness of the fragments.

Arguing upon this we are led to the conclusion that a continuance of this process must produce molecular magnets.

If we place magnetic bars in contact with each other, the north and south poles alternating and in contact with each other we obtain a metallic chain of considerable strength, although its component parts are not mechanically connected together. The closer the contact of the ends of the bars the stronger will be the chain.

If with isolated bars we can obtain a connecting force equal to many pounds by close contact, how much stronger must be the connecting force when exerted between molecule and molecule.

Such an argument undoubtedly leads to the conclusion that bars saturated with magnetic force should certainly be stronger than those that are not.

Faraday announced that "there existed lines of force within the magnet of the same *nature* as those without. What is more there are exactly equal in *amount* with those without. They have a relation in *direction* to those without; in fact are continuations of them, absolutely unchanged in their nature."

To determine the effect of magnetic force upon the tensile strength of Iron and Steel,* bars of each were selected and cut into suitable lengths for use in the breaking machine and numbered.

Nos. 1, 3, 5, etc., were broken in the usual manner.

Nos. 2, 4, 6, etc., whilst in the breaking machine were surrounded by a suitable coil of copper-wire, through which a current of galvanic electricity was passed during the operation of breaking.

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*The Steel employed in the experiment was "Jessop's Round Machinery," ½ inch rod—

and broke at $\begin{cases}\text{maximum, 127,934 lbs.}\\ \text{minimum, 125,694 lbs.}\end{cases}$

per square inch of section.

The Iron broke at $\begin{cases}\text{maximum, 59,948 lbs.}\\ \text{minimum, 56,887 lbs.}\end{cases}$

per square inch of section.

The results obtained from the magnetic Steel bars were about one per cent. less than those obtained from the non-magnetic, and from the magnetic soft Iron bars about three per cent. less than from the non-magnetic.

Both the Steel and Iron bars became heated whilst within the influence of the current of electricity, the soft Iron more so than the Steel.

It occurred to me that the depreciation of strength might have been caused by the rise of temperature† in the bars, and I accordingly prepared permanent magnets from alternate sections of a steel bar and repeated the experiments comparing the cold magnets with the unmagnetized sections of the same bar. The results showed no appreciable difference in strength between the magnetic and non-magnetic sections.

To test the matter still further, bars of Steel were so magnetized as to present a pole at one end, the other in the middle of the bar, with one end neutral, that is, one end of the bar attracted the North or South pole by a magnetic needle and repelled the South or North, and the other end of the bar attracted either pole of a magnetic needle.

Under these conditions if there was any effect to be had from the influence of the magnetic force, the bar should incline to break either at the central pole or at the neutral point between the poles.

The results of the experiments showed that there was no inclination to a choice of either location as the place of fracture.

The conclusion arrived at, is, that *the condition of magnetic polarity does not in any way influence the strength of steel bars.* With reference to the soft iron bars the comparison was not made, for the reason that they would not remain magnetic unless surrounded by the galvanic coil, in which case they became heated by the action of the current.

How far a change from fibrous to crystalline structure is affected by the influence of magnetism has not been ascertained, or whether there is any deterioration of the strength of iron or steel on such account.

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†For effects of temperature upon the tensile strength of Iron, see Report of the Committee of the Franklin Institute of Pennsylvania,—" upon the strength of materials employed in the construction of Steam Boilers." Experiments made at the request of the Treasury Department of the United States (Jan'y 4th 1831—Jan'y 5th 1837.)

Iron telegraph wires, in the course of time become brittle, and to such an extent that if the usual method of uniting them by winding each upon the other is attempted, they are frequently broken in the process.

From this it would appear that a passage of a strong galvanic current produces some molecular change effecting the strength of iron. Such conducting wires, however, are not necessarily or even usually magnetic. There can be no doubt, however, as to the deteriorating effect of *galvanic* force as an accelerator of oxidation or the solution of a metal.

Observations upon Iron Bridges and structures subjected to atmospheric influences and upon Boilers exposed to the action of heat and the chemical agents contained in ordinary waters lead to the conclusion that galvanic force is usually as great, and frequently a far greater cause of deterioration than mechanical wear. Indeed all of the operations of nature, organic and inorganic, both constructive and disjunctive, involve the production of more or less galvanic force or are the results of its action.

Motion, unaccompanied by any other apparent change than that of place, is a desturber of electric or galvanic equilibrium, and the converse is equally true. If it were possible to produce perfectly pure and homogeneous iron, then the generation of destructive galvanic currents by the contact of sheets or bars would not take place.

By exercising care in the selection of iron, especially that used for steam boilers, the deterioration from galvanic action can be reduced to a minimum.

Many steam boilers have come under my observation in which the corrosion was but slight, and affected all parts equally, others in which the metal of a single sheet only was attacked, the corrosion of which sheet protected the remainder of the boiler almost as efficiently as if the sheet had been replaced by one of the metal zinc.

The most striking instance of the effect of introducing a sheet of metal of greatly differing electro-condition, that occurs to me, is that of a boiler which had been in use for a considerable length of time without showing any unusual tendency to corrosion, when from some cause it became necessary to replace a sheet by a new one.

The result of the introduction of a new sheet was to set up at once a strong galvanic action by which every sheet in the boiler was corroded except the new one.

Samples of iron cut from the edges of the old and from the new sheets were placed in a bath to which a few drops of dilute acid were added and a connection made with a galvanometer, resulting in the production of a new current; the purer iron corroding, and protecting that which contained the greatest amount of carbon.

The inciting cause of the galvanic action was therefore judged to be the introduction of a sheet of iron electro-negative to those already in the boiler, its position in the electro-chemical scale depending upon the amount of carbon it contained.

The injurious effect consequent upon the junction of masses of wrought iron of varying electro-chemical properties, is, therefore, increased when *steel* is joined to wrought iron, as is frequently the case in locomotive boilers in the tubes and tube sheets.

Again by the junction of *cast iron* to steel or to wrought iron, the destructive effect is greatly intensified, and at times becomes quite as violent as when copper is made an element in the galvanic circuit in connection with wrought iron.

The necessity for the selection of iron with reference to its electric condition, applies equally to the material employed for Bridges or Vessels or Boilers or any structure which is to be built up from separate sheets and bars of iron.

It is or ought to be the habit of careful constructors to cut sample pieces from every sheet or bar of metal worked, and to make a trial of their quality by bending hot and cold, and to make frequent tests of tensile strength. Examinations as to electric-chemical condition can be made with equal facility. Determinations of the composition of the metal or of the percentage of carbon in it by chemical analysis are unnecessary; an ordinary workman furnished with a coarse galvanometer and a weak acid bath can ascertain the exact electro-condition of each sheet or bar more rapidly than he can examine the quality by the ordinary tests of bending on an anvil, hot and cold. With the metal of Bridges, Vessels, and especially Steam Boilers, the deterioration by corrosion is more to be feared than is mechanical wear.

Galvanic corrosion acts with greater vigor in locations that are usually inaccessible, such as the interior of joints or defective sheets or parts that are closely approximated, and the mischief is only suspected when it has progressed to such a degree as to become evidently

dangerous and the parts are in condition to require immediate attention and repair.

Attention to the precautions enumerated for securing mechanical and chemical fitness of the metal to be used for structures of iron, will undoubtedly promote economy and safety.

NOTE BY THE EDITOR OF THE JOURNAL.—It must be always remembered by the readers of the JOURNAL, that the Franklin Institute does not assume any responsibility for the statements or opinions advanced in papers which may appear in its pages, neither is the Institute in any way compromised by the views of the editor whenever he may express them.

The first portion of the foregoing paper carries with it, in negative results, an antidote to the evil of promulgating an occult reason for strength or weakness of iron. Some of its statements are a little questionable ; for instance, it may be doubted if a bar or structure of *iron*, pure and simple, acquires magnetic polarity, or rather, retains it under any circumstances. It is generally known that all the iron of commerce, or in use for structural purposes, is *steely* to some degree, and the extent of the nature of steel in the material is in some ratio a limit to its capability to assume permanent magnetism.

The effect of the position of a vessel with regard to the points of the compass, when in construction, has been thoroughly investigated and determined ; the value of that effect, however, is so influenced by the dissimilarity of the plates or bars in proportions of carbon, and by differences in the application of force upon them, by hammering, or in other ways, as to be very indefinite.

The reasoning that a magnetic bar should be stronger than one not magnetized, on a theory of internal subdivision, is somewhat wanting in logical force. It is difficult to comprehend how the attraction should multiply, except on the argument that two halves of a string are stronger than a whole one.

If the law were good, the subdivision need go no farther than Joule's celebrated magnets, where a fragment of iron of one-half grain weight supported by attraction a quarter of a pound (or 3500 times its own weight). This proportion would add nearly 56 lbs. for each sixteenth of an inch of length of bar of one square inch section—11,000 lbs. per foot of length.

It is very certain, that telegraph wires are *not* impaired in the least by the electric currents of service. Telegraph wire is hard drawn or rolled, and galvanized by a coating of zinc, and when laid at rest, without excessive tension, will last some unknown length of time. When strained from poles placed at great distances apart, contracted by the winter cold to the tension of a harp-string, when the gentle zephyrs from the northwest have played on them for many months, when occasional loads of ice of eight or ten times their own

weight have tested them—then the wire may be found to have become so brittle that it cannot be wound around its own diameter of 5-16 of an inch, with impunity.

But this part of the paper terminates very satisfactorily. Magnetism did not strengthen iron. It is the second portion not so conclusively disposed of, that leaves behind a possible assumption of dangerous character. It is a serious mistake to admit as a popular utterance, that we must look to "galvanic (voltaic?) force" as the *cause* of deterioration of boilers, or of iron structures of any kind. It is very certain, that an electric current produced by a voltaic battery will decompose a solution of a salt, and cause a crystal to be formed at one pole, and a gas to be eliminated at the other. It is also certain, that two dissimilar metals, in a bath of acid, which from chemical affinity will attack either, will act by the destruction of the one for which the acid has the greatest affinity, and a voltaic battery will be formed from which electrical currents can be taken. It may be admitted, that no deposition in crystalline form occurs without the agency or accompaniment of a current of electricity, and that no decomposition of metals by rusting is *unattended* by the development of a current. But the acid that destroys, and the salt that deposits, are precedent to, or coincident with the voltaic currents.

It is questionable, if at any temperature below the highest used in steam boilers, either iron or steel (iron with a small quantity of carbon in intimate but not chemical combination) will rust in pure water divested from oxygen. The acids requisite for the slow destruction of the boiler are supplied by the presence of oxygen. The presence of oxygen by absorption in all water, and its evolution by heating of the water, beside the vegetable acids generally to be found in small quantities, the decomposition of chloride of sodium, to some degree, when salt water is used; and the fat acids derived from tallow and oil, when condensed water from the exhaust of an engine is pumped back; all these supply acid requisite for the slow destruction of a boiler. The carbonate and sulphate of lime, which form the bases of incrustations are to be found in most waters, and in great abundance in some.

A perfectly homogeneous condition in the electro-chemical state of all the material of the boiler *might* be a protection from rusting of any part, and prevent the establishment of electric currents and preclude incrustation, but the equilibrium would be excessively unstable; the difference of temperature would obviously disturb it, and the supposition with our knowledge of the constituents of iron, either in the crude product or the finished material, is simply impossible. The effect of differences of heat on the electro-chemical condition of a piece of iron is quite equal to that proceeding from the presence or absence of small quantities of carbon. While the balance of

evidence is that without free (possibly ozonized) oxygen in water, iron of any grade (not spongy) will not decompose it at ordinary temperature; yet pure iron is acted upon with the greatest facility.

Pure iron, also, is nearly incapable of being worked in the furnace without burning up—as iron approaches purity it becomes workable without excessive waste only in Siemens' furnaces, where the gases of combustion are free from oxygen—and pure iron has very little comparative tenacity, and great ductility. Iron on the other hand, with an almost imperceptible proportion of carbon, (and possibly some other substances as substitutes), is tenacious, unyielding to near the point of rupture and suitable for boiler plates. With another small addition to the carbon, the iron becomes low steel, or so-called homogeneous iron, of yet greater strength and suitability. With other ratios of carbon there is found steel not suited for boiler work by hardness, although the strength may be further increased.

Imagine it to be feasible "for an ordinary workman with a coarse galvanometer and a weak acid bath," to select these qualities, the operation would be highly satisfactory if iron boiler plates were found in these four conditions solely. But there are other kinds of plates.

The exact place of the plates in their electro-chemical state does not detect the small increment of phosphorus or sulphur, and the iron may still be worthless. The remedy is simple: "Cut sample pieces from every sheet, 'bend them hot and cold,' and make 'frequent tests of the tensile strength.'" Following all these precautions and we shall have a great many professors and very few workmen, and our mechanics will go to less critical countries.

We shall, without doubt, have acquired a degree of excellence not yet attained, and until other precautions are suggested, such as the disuse of piled plates, because some have blisters, the use of drilled holes, because some punchings are imperfectly done and strain the sheet, etc., boiler making will have taken a step towards *perfection.*

In short, the improvement of boiler practice must move in the track already laid. Responsibility must urge upon the user of a boiler the necessity of excellence, and emulation must do the rest. The iron manufacturer will emulate to supply iron *better* suited, the workmen boilers better made, and the engineer boilers better planned. The scientific man can help them all, but he cannot make philosophers of them.

The question now really open to consideration is either how to obtain water free from injurious substances, or else to allow such substances to act upon some material, zinc for instance, for the protection of the iron. When this is settled, the destructive "galvanic (voltaic?) force" will be found to have disappeared.

FAYE—ON THE METEOROLOGICAL THEOREM OF ESPY.*

"A current of descending air can never be cold, for the current "warms itself by its own compression, at least in the normal state of "the atmosphere. There can then result neither rainfall nor the "condensation of the aqueous vapor in the strata traversed by it, but "rather something similar to that which one observes in the sand "storms of Africa and Asia."†

From this celebrated theorem, its author concluded some thirty-five years ago, and we still to-day conclude with him, that the movement of the air in our hurricanes, cyclones, water spouts, and tornadoes, can only be ascending: an idea so conformable to the old prejudice, according to which water spouts and tornadoes draw the water of the sea up to the clouds, that it was immediately adopted. This theorem as expressed by its author, and after him by nearly all meteorologists, is not to be accepted. It contains, however, something of that truth and usefulness which so forcibly impressed the Academy when Espy, in 1840, came to submit his labors to it. But so much of truth as I shall have occasion to deduce from this theorem, leads to some conclusions quite different from those which to-day are ordinarily connected with the preceding principle.

Let us enclose, high up in the atmosphere, by the aid of a cylinder and piston, impermeable to heat, some air taken at its natural pressure, p, and at its temperature, t; then let us force this apparatus to descend, traversing successive layers of atmosphere to the ground, where the final pressure is p'. What then will be the temperature, t', of the air thus compressed within the cylinder? This is a simple question of thermo-dynamics, the solution of which is given by the well known formula

$$T' = T \left(\frac{p'}{p}\right)^{1 - \frac{1}{\gamma}}$$

* Translated by C. Abbe from *Comptes Rendus, Paris*, vol. 81, p. 109.

† Extract from the report of Messrs. Arago, Pouillet and Babinet, (*Comptes Rendus*, 1841, vol. 12, p. 454, etc.) Mons. Peslin presents very clearly the same theorem. (See *Comptes Rendus*, May 10, 1875): "I have demonstrated that if the movement be descending, as Mons. Faye would have it, then, first, there could not be any rain; second, the wind in a tempest would be very warm and very dry, and would present to an eminent degree, the characteristics of the wind called in Switzerland, Foehn. In a preceding article of the 12th of July, I have discussed the opinion of Meldrum, that has been by some opposed to my views."

γ being the ratio of the specific heats of the air at constant pressure and constant volume; T and T′, the absolute temperatures corresponding to the initial and to the final pressures p and p'. In Mr. Espy's time, thermo-dynamics did not exist, but we had an equation of La Place, as written thus by Poisson,

$$t' + \frac{1}{a} = \left(t + \frac{1}{a}\right)\left(\frac{p'}{p}\right)^{1-\frac{1}{\gamma}}$$

Where t and t' are the ordinary temperatures, and a the coefficient of dilatation of the air. At present, it is known that this latter equation is identical with the preceding; for $t + \frac{1}{a}$ is nothing but the temperature T, counted from the absolute zero. Mr. Espy has then, in 1840, correctly performed his calculations, and the Commission of the Academy, in 1841, has been able to assure itself as it has said, of their satisfactory exactness, without knowing a word of thermo-dynamics, without suspecting even, the meaning that this science to-day assigns to the reciprocal of a. Moreover, the numerical values of a and γ were known even then with a precision far greater than was necessary for these calculations.

Let us take for example, as has been done by Peslin, who has reproduced under a slightly different form some calculations of this kind, some air at 5000 meters altitude. In the normal state of equilibrium attributed to the atmosphere at this height, the temperature of this air should differ by 30° centigrade from the lowest stratum (a vertical decrease being supposed of one degree for 175 meters in altitude.) Making then for the lower strata $t' = 30$, and $p' = 0{\cdot}76^{m}$, and for the upper stratum, $t = 0$, we find, supposing the barometric formula of La Place applicable to this case, $p = 0{\cdot}42^{m}$. We have for the reciprocal of a, 273° (it was 266° in 1840) and as the normal air taken at an altitude of 5000 meters, and at 0° temperature contains very very little vapor, we should have to make $\gamma = 1{\cdot}41$, as for dry air. This air being by its compression forced further and further from its point of saturation, the above formula is applicable. It gives $T' = 324°$, whence $t' = 51°$. Thus the temperature of the air when it arrives at the bottom has been elevated to 51° by the compression that it undergoes, supposing as we have done, that there has not taken place any exchange of its heat with the surrounding air. Its excess of temperature with reference to the lower air will be 51° — 30° =

21°. If it were saturated with moisture at an altitude of 5000 meters, it would be of extreme dryness on arriving at the ground.

But, in reality, the descending air traversing the atmospheric strata, will continuously give up its heat to these latter, according to an unknown law, and will receive aqueous vapor from them. This places us face to face with a new problem, where the cylinder referred to in enunciating Mr. Espy's theorem, can no longer be supposed impermeable to heat.*

In the second place, the supposition that we have made of an atmosphere in the normal state of equilibrium, excludes precisely the great perturbation that we are studying. The preceding theorem ought, then, strictly to be reduced to the following: The normal air of the upper regions being forced by descending to traverse successive strata also in their normal condition, tends at each instant to acquire a temperature superior to that of these strata. It will arrive at the ground with a temperature a little superior to that of the last or lowest stratum, and in a state of much greater dryness. The contrast between these will depend upon the velocity of the descent and upon the nature of the contact of this air with the strata traversed by it. And it is necessary to add that this proposition is inapplicable to all other cases, for if, beside the vapor of water this descending air should drag with it, or receive *en route* some water in a vesicular state like that found in the clouds, the preceding calculation would signify absolutely nothing. The air thus mixed with liquid particles would tend to maintain itself during its descent in a state of saturation, and the heat acquired by its increasing compression would be employed in vaporizing the aqueous vesicles at the rate of from 606 to 594 calories per kilogram of water, (between 0 and 20° temperature) under whatever form this liquid water presents itself. Let us suppose simply to fix our ideas that the air dragged into the descending current contains two per cent. of its weight of vesicular water, which is not even equal to the quantity of water contained in a state of invisible vapor in the lower stratum of air at the point of saturation. In order to vaporize this water, there will be necessary 12 calories for each kilogram of misty air, whilst the compression of the gaseous part as calculated above would itself produce only 12 calories. The phenomena as above described would, therefore, be reversed, the

* See Hirn's mechanical theory of heat, 3d edition, vol. 1, page 296.

upper air would traverse the successive strata, preserving a lower temperature, and would take heat from them in place of giving it to them; it would arrive at the ground colder than the lowest strata, and absolutely saturated, and even still preserving some vesicular water. These ideas are immediately applicable to water spouts. The cold air of the upper regions traverses the thick strata of clouds to whose increase it contributes, and draws with it into the lower transparent strata the material of these clouds which seems to form a vaporous prolongation of them downwards, under the ordinary conical form of a whirl; a quick gyration by accumulating the opaque and heavy particles at its circumference will produce around the descending column a nebulous sheath, more or less opaque,—at least, in so far as the heat and the dryness of each stratum thus traversed does not suffice to transform the whole into vapor, and then the water spout will become transparent in this portion. But ordinarily in full activity and in moist weather, it remains opaque down to the ground, or to the surface of the sea. This entire reversal of the effects predicted by Espy will be still more marked, if in the upper air there are found mixed with it the cirrus clouds which one sees constantly appearing in the upper currents as precursors of storms, and afterwards participating in the gyratory movement which produces them; for then it is no longer the atoms of water that need to be vaporized, but needles of ice whose temperatures are often far below that which we have adopted for a purely fictitious state of equilibrium.

This glacial air, charged with particles of frozen water, which descends by whirling over a vast circular space, traversing strata already saturated with moisture, gives rise, first, to an abundant precipitation of vapor; secondly, to rain, or even to the formation of hail, which so often accompany cyclones*. And if these various products, air, vapor, and drops of rain arrive at the soil with their temperatures differing but little from that of the last stratum, it is because they are rewarmed in traversing the intermediate layers. We see how far Espy was from applying his theorem to tempests, cyclones, hurricanes, etc. The only application that it is permitted to make of it, in my opinion,

* The constitution even of these hailstones is in accordance with this theory, and shows that the icicles of the very cold cirri agglomerating in the gyratory movement, which tends to accumulate them at its circumference, encounter alternately in their circular descent, layers of air simply saturated with vesicular water, which produces a transparent crust, and strata containing frozen particles, the re-union of which produces an envelope opaque like the nucleus.

is that which we have already indicated above. Let us take the first example, and consider our cylinder (always impermeable to heat, but supposed actually without gravity) at the moment when it is just above the ground. If the next instant we let it go, it will re-ascend in virtue of its surplus heat, like a hot air balloon, until it attains its primitive altitude, while its piston will rise little by little by the relaxation of the interior air. Now, a similar atmosphere, very nearly deprived of vesicular water, is encountered at every altitude above certain sandy regions, to which the great upper currents of the atmosphere arrive, only after having been deprived of their cirri and other clouds by the well-known action of high plateaus or chains of mountains placed in their way. If the gyratory movements which are formed in the ærial currents happen to pass above such deserts, they bring down only more of the super-heated air of an extreme dryness. This air, lighter than the surrounding air, will tend then, when once it is disengaged from the gyratory motion by the resistance of the soil, to re-ascend tumultuously all around the whirlwind, and, moreover, it will ascend the higher, in proportion as in descending more rapidly, it may have given out less heat to the strata traversed by it. Then the torrents of sand swept up from the soil and projected afar by the geometrically circular work of the cyclone will be carried tumultuously upwards, all about the latter by the air which has just escaped from it, when seized by the prevailing winds, they will be transported to great distances. But it is not the whirlwind itself which will have elevated this torrent of dust into those upper regions, as it is generally thought; but it is, on the contrary, the ascending counterpart of the phenomena which produces this effect, and consequently those distant transports of clouds of dust so well studied by Tarry.

This same theorem of Espy, when restricted to its true field, reduces to nothing the hypothesis of descending cyclones, of beautiful weather, with decreasing temperatures, that Hildebrandsson recently explained in a memoir otherwise very interesting, where, after having repudiated my ideas, he substantially restricts the movements of the atmosphere to two kinds of winds: the ascending winds of bad weather, and descending winds of beautiful, and often cold weather. Thus we see that the truth as contained in the theorem of Espy is reduced to a very small item, and this part is completely in accordance with the idea I have entertained. This history is instructive. It shows

how much our mind is inclined, even in a very simple mathematical study of natural phenomena, to lose sight of the conditions or the suppositions which alone have prompted the employment of this powerful instrument and to formulate general conclusions which we imagine to have been demonstrated with the rigor of the formula and figures. I have still some remarks upon another subject before closing. I have shown that the pretended storms of aspiration should be incapable of changing their place, and consequently of presenting the grand phenomena of movement of translation which brings into our climate the cyclones primitively formed in the torrid zone. Mohn has set forth, in his beautiful study of the storms of Europe, the fact already recognized in other regions near the equator, that it ordinarily rains more in advance of the cyclone than in the rear; and he has concluded thence that a rarefication is produced in advance. This latter should determine the entire cyclone to advance as a whole in the direction where the atmosphere presents the greatest humidity. My reply is: first, the cause assigned should tend to indefinitely elongate the cyclone towards the front, and not to make it march along as a solid body; second, there should be in its advance a vast barometrical depression, such as in fact exists only at the interior, and whose maximum is found at the centre; third, the cyclones moving constantly from the equator, march toward the higher latitudes, whilst the humidity, on the contrary, increases from the higher latitudes towards the equator; fourth, in the hypothesis of storms of aspiration, however slightly gyratory, like those of Mohn, there would not be any constant ratio between the direction of a stream of air moving inwards below, and that of the same air after it takes a centrifugal movement outward, above; fifth, in fact, the water-spouts, which are also cyclones, advance very easily, without there falling a drop of rain.

As to the general movement of the lower atmosphere invoked by Messrs. Espy and Peslin, it affects almost always a direction entirely independent of that of cyclones, great or small, or rather it is zero. The truth is far more simple. The cyclones follow the advance of the upper currents, where they have their birth, and these currents have not any direct relation to the actual state of the lower atmosphere.

There remains a calculation wherein Peslin undertakes to show that the gyrations of cyclones ought to result from the rotation of the earth. I will request my friend to extend a little farther, to the fifth degree of latitude, for example, the calculation that he has made for the forty-fifth degree. Some of the water-spouts and tornados have a violent gyration; and for some cyclones themselves, it is very clear that the cause indicated does not exist. Mr. Peslin has even pretended that some of these phenomena, so eminently gyratory, ought to be banished from the category of cyclones. Ought I to speak of the barometric depression which we have cited so often as a palpable proof of the power of aspiration? Undoubtedly the level of the sea tends to elevate itself under any cyclone, by virtue of this barometric depression, the latter being from one to five centimeters of mercury; and the change in the level of the ocean corresponding thereto tends to elevate it from one to six decimeters.

I believe I am able here to close this long discussion, where I have occupied myself, exclusively with facts. My researches upon the mechanical constitution of the sun, have led me at first to questions new to me. Perhaps I have thus contributed to dissipate the prejudices that have weighed heavily upon one of the most interesting of our sciences, by putting in full view, and explaining the beautiful laws of tempests, so necessary to our mariners, and so strangely misconceived to-day; to prepare finally the experimental base in which the mechanics of the gyratory movements in fluids have, until now, been deficient. If it is so, it will be correct to say that studies purely solar, have thrown some light upon terrestrial phenomena.—*Paris Comptes Rendus*, vol. 81, pp. 109 to 115.

The Wonders of the Microscope.—The last number of the *Microscopical Journal*, (Sept. 1), describes the existence of Flagella (tails or probosces) in Bacterium termo. The body of this object is warp-shaped and measures, each part, about 1-14,000 an inch in length, and 1-45,000 an inch in breadth, and has been before observed. It is now seen to have a "flagella" at each end about as long as the two parts of the body, or 1-7000 part of an inch, and not to exceed 1-1,000,000 an inch in width, and so *thin* as to be undiscernable on the side view. This "flagella" has muscular power and coils and lashes rapidly.

The limit of microscopic observation is not yet reached, and each new attainment has merely been made to be surpassed.

PHYSICAL PROPERTIES OF CARBONIC ACID.

By John W. Nystrom, C.E.

The strange action of carbonic acid has at all times occupied the attention of operative minds speculating to use the same for motive power, but we have heretofore not had sufficient experimental data to define its law of action. The late experiments on carbonic acid, made by Dr. Andrews, published in the September number of this Journal, are therefore welcome to those who labor on that subject.

The object of this article is to treat Dr. Andrews' experiments with sufficient mathematics to render them more available in practice.

V = volume of carbonic acid gas of temperature T, centigrade, and of pressure P in atmospheres, compared with the volume at zero centigrade, and under atmospheric pressure.

(1) Volume $V = \frac{1}{P} + \frac{T - 1{\cdot}4P}{200P}$

(2) Temperature $T = P(200V - 1{\cdot}4) - 200.$

(3) Pressure $P = \frac{T + 200}{200V - 1{\cdot}4}$

The pressure varies, inversely as the volume, when $T = 1{\cdot}4P$.

The following table I is calculated from these formulæ.

TABLE I.—Volume of Carbonic Acid Gas of different Temperatures and Pressures.

Centigr'de Temp. T.	Pressure, P, in Atmospheres.					
	1	10	20	30	40	50
0	0·993	0·093	0·0430	0·02633	0·01800	0·013
10	1·044	0·098	0·0455	0·02800	0·01925	0·014
20	1·098	0·103	0·0480	0·02966	0 02050	0·015
30	1·148	0·108	0·0505	0·03133	0·02175	0·016
40	1·198	0·113	0·0530	0·03300	0·02300	0·017
50	1·248	0·118	0·0555	0·03466	0·02425	0·018
60	1·298	0·123	0·0580	0·03633	0·02550	0·019
70	1·348	0·128	0·0605	0·03800	0·02675	0·020
80	1·398	0·133	0·0630	0·03966	0·02800	0·021
90	1·448	0·138	0·0655	0·04133	0·02925	0·022
100	1·498	0·143	0·0680	0·04300	0·03050	0·023
110	1·548	0·148	0·0705	0·04466	0 03175	0·024
120	1·598	0·153	0·0730	0·04633	0·03300	0·025
130	1·648	0·158	0·0755	0·04800	0·03425	0·026
140	1·698	0·163	0·0780	0·04966	0·03550	0·027
150	1·748	0·168	0·0805	0·08050	0·03675	0·028

The volume corresponding to $T = 0$ and $P = 1$, should be the unit 1, instead of 0·993 in the table, but the course of Dr. Andrews' experiments indicate that the primitive volume had been 0·993.

When the temperature is expressed by Fahr. scale, the formula for volume will be

(4) $$V = \frac{1}{P} + \frac{(T - 32) - 2{\cdot}52P}{360P}$$

When the pressure is expressed in pounds per square inch $= p$, and the temperature by Fahr. scale, the formula for volume will be

(5) $$V = \frac{14{\cdot}7}{p} + \frac{(T - 32) - 0{\cdot}1743p}{24{\cdot}49p}$$

Dr. Andrews' experiments extend only to three temperatures and three pressures, which is not sufficient for determining the law of volume which requires at least five points of temperatures and pressures. Any kind of curve can be drawn through three points.

The data given by Dr. Andrews indicate that his experiments have been made with great care and precision, and I hope he will complete the experiment to the requisite five points of temperatures and pressures.

The following table is respectfully submitted to Dr. Andrews to fill up, in order to establish the law:

Centigrade Temp. T.	Pressure in Atmospheres.				
	1	10	22·26	31·06	40·06
0·	....	....	....	....	....
6·05	....	....	0·03934	0·02589	0·01744
20·	....	....	....	....	....
63·7	....	....	0·05183	0·03600	0.02697
100·5	....	....	0·05909	0·04160	0·03161

In all kinds of experiments where a quantity depends upon two independent variables whose laws of variation are unknown, a table of this kind should be completed in order to establish the sought law. When carbonic acid evaporates from liquid to gas, or condenses from gas to liquid, the relation between the temperature and pressure is as follows:

T = temperature Fahr. of the liquid and gas.

P = pressure in atmospheres.

(6) $$P = \frac{(T + 260)^4}{208513600}$$ log 8·3191344.

(7) $$T = 120{\cdot}17 \sqrt[4]{P} - 260.$$ log 2 0797838.

p = pressure in pounds per square of carbonic acid vapor.

(8) $$p = \frac{(T + 260)^4}{1421700}$$

log 7·1527888.

The above formulæ are deduced from the experiments of Pelouse and Faraday. It appears from those experiments that carbonic acid freezes to solid at the temperature 260° Fahr. The freezing point of liquid carbonic acid is variously given by different authors. Olmstead says —85°, but Faraday experimented with liquid carbonic acid at —148° without it freezing.

TABLE II.—Properties of Carbonic Acid Evaporating from its Liquid, or Condensing from Gas.

Pressure.		Fahr.	Pressure.		Fahr.
Atmos., P.	Pounds, *p*.	Temp., T.	Atmos., P.	Pounds, *p*.	Temp., P.
0·0	0·0	— 260	15	220·5	— 24
0·1	1·47	— 192	20	294	— 6
0·2	2·94	— 180	25	367·5	+ 9
0·3	4·41	— 171	30	441	21
0·4	5·88	— 164	35	514·5	32
0·5	7·35	— 159	40	588	42
0·6	8·82	— 154	45	661·5	51
0·7	10·29	— 150	50	735	59
0·8	11·76	— 146	60	882	74
0·9	13·23	— 143	70	1029	88
1	14·7	— 140	80	1176	99
1·5	22·05	— 127	90	1323	110
2	29·4	— 117	100	1470	120
2·5	36·75	— 109	110	1617	129
3	44·1	— 102	120	1764	138
3·5	51·45	— 96	130	1911	146
4	58·8	— 90	140	2058	153
4·5	66·15	— 85	150	2205	160
5	73·5	— 81	160	2352	167
6	88·2	— 72	170	2499	174
7	102·9	— 65	180	2646	180
8	117·6	— 58	190	2793	186
9	132·3	— 52	200	2950	192
10	147	— 47	220	3234	207
12	176·4	— 36	238	3500	212

The preceding table, II, is calculated from the formulæ, and agrees with the experiments of Dr. Andrews, as follows:

Temperatures.	Pressures.	Atmospheres.
Fahr.	Andrews.	Nystrom.
32	35·04	35.
72	61·13	59.
83	70·3	67.

Dr. Andrews' experiments give higher pressures at high temperatures than my formulæ, which correspond with the experiments of Pelouse and Faraday.

THE QUANTITIES OF AIR, CARBONIC ACID GAS, MOISTURE AND HEAT ACCOMPANYING RESPIRATION.

The following is a note of interest as relating to important questions in ventilation. The inquiry of Dr. Smith is the most complete one made to this day, and a summary of its results accompanied with an estimation of corresponding heat and moisture will prove advantageous in some cases.

NOTE UPON DR. EDWARD SMITH'S inquiries into the phenomena of respiration. Proc. Roy. Soc., 1859, vol. ix, page 611, et seq.

Four persons were experimented upon, viz.: Prof. Frankland, Dr. Murie, Dr. Moul, and Dr. Smith (the writer.)

The result of experiments showed 18 to 20 respirations per minute of 39·5 to 30 cubic inches of air for each respiration. There were 4·63 to 5·72 pulsations to a respiration, the younger person of the four having the least number.

The quantity of air equals 583 to 365 cubic inches per minute. [If it is assumed that the air was at 62° and had 65 per cent. of humidity = ($54\frac{1}{2}$° dew point) = 527·4 grains of air per cubic foot, or 0·305 grains per cubic inch.]* The quantity then equals 178 to 111 grains of air per minute. The carbonic acid gas emitted varied from 10·43 grains to 6·74 grains per minute—equals 1 grain to 54·7 cubic inches to 1 grain to 58 cubic inches of air—or about 6 per cent. of the air exhaled was carbonic acid gas. Taking the fresh air of inhalation to have been 77 per cent. A + 23 per cent. O ∴ that exhaled becomes $77A + \frac{408}{22}O + [C\frac{36}{22} + O\frac{96}{22}] = 77A + 18{\cdot}55O + 6\overline{CO_2} = 101{\cdot}64$ ∴ a gain of weight for constant volume at 62° of $1\frac{2}{3}$ per cent. The volume being unaffected by the chemical union of a part of the oxygen with carbon from the blood. Supposing the air to have been inhaled at 62°, and supposing also that the breath was exhaled from the nostrils or mouth at 90° without change of dew point, the volume would have become, if air only, $\frac{527}{500}$, but if loaded with moisture, $\frac{527}{494}$. The effect of heat upon density of carbonic acid gas may be taken as the same as upon air. Whence the density of the expired breath at 90° compared with that of fresh air at 62° $= \frac{494}{527} \times 1{\cdot}0164 = 0{\cdot}9532$. The emitted breath being nearly 5 per cent. less weight than the fresh air.

The quantity of moisture in air of 62°, and $54\frac{1}{2}$° dew point (= 65

*Glaisher's table, barometer at 30″, Guyot, have been used for the figures given as sufficiently accurate for the estimate results.

per cent. humidity) is 4 grains per cubic foot, that in air of 90°* saturated is 14·5 grains, and for 1·05 cubic feet of air equals 15·2 grains—addition of moisture (extracted from the lungs, etc.) = 11·2 grains per cubic foot.

This quantity of moisture per cubic foot of air inhaled gives to 178 or 111 grains of air per minute = 3·7 grains to 2·3 grains of moisture per minute.

The removal of oxygen from the air equaled $\frac{4·45}{23·00}$ or 18·5 per cent. of the entire quantity of oxygen present.

RESUMÉ OF RESPIRATION EACH MINUTE.

0·338	to 0·211	cubic feet	of fresh air	at 62° inhaled.
178	to 111	grains	"	" "
10·4	" 6·7	"	" carbonic acid	at 90° exhaled.
3·7	" 2·3	"	" vapor	" "
171·2	" 106·2	"	" impure air	" "
185·3	to 115·2	"	" total exhalation	at 90°.

The quantity of carbon taken up = $\frac{6}{22}$ of the carbonic acid gas =2·85 to 1·82 grains of carbon consumed in the lungs.

An examination as to the quantity of heat developed by the combustion and absorbed by evaporation is as follows:

The total heat of carbon burnt to carbonic acid gas = 14·500 units = 2·07 units per grain. (In this case the total heat is given out, as but 28° of elevation of temperature of escaping gases is allowed.) Whence, there are given out each minute,

5·75 to 3·73 units of heat.

The heat abstracted for vaporization = 1062 units per pound of water 98° to 90° (the temperature of the lungs being assumed at 98°) = 0·152 units per grain of same temperature. Whence, there are expended in formation of vapor in the lungs per minute,

0·56 to 0·35 units of heat.

Demanding about one-tenth the heat produced by combustion of carbon. The quantity of heat expended on heating the air of respiration ∴ 178 to 111 grains per minute × 0·238 (specific heat of air)

* It is not proper to assume this moisture to exceed the saturation of air at 90°. It is certain that the nostrils or mouth do not exceed this temperature, or certainly 92°, and that if more moisture than saturation were exhaled, it must condense in them to the final elevation of temperature of these parts. The breath does not show any indication of excess of vapor, except when expelled into colder, nearly saturated air.

$= 42$ to $26 \times 28°$ (elevation of temperature $62°$ to $90°$) $= 1176$ to $728 \div 7000$ (grains per lb.)

$$= 0{\cdot}17 \text{ to } 0{\cdot}10 \text{ units of heat,}$$

or about two-sevenths the quantity expended in formation of vapor.* These figures leave nine-tenths of the heat evolved to be expended in radiation, convection, and evaporation from the surface of the body and in work. The foregoing figures are maximum and minimum for the *working* day.

The author gives for a day's combustion of carbon,

0·414 lb. to 0·280 lb.

Dr. Smith and Prof. Frankland being the exemplars—equivalent to the general average of carbonic acid gas per minute,

7·305 grains to 4·98 grains.

The quantity of carbonic acid gas increased after each meal and declined from the largest quantity with some uniformity of rate. It also increased with exercise and fell off at rest—in profound sleep to 4·5 grains per minute, and to 6·1 grains at other moments in the night, and decreased as the temperature rose.

The effect of increase of temperature (neither heat or dew point stated) was that the quantity of air was decreased 30 per cent., the rate of respiration 32 per cent. and the carbonic acid 17 per cent. [From this it would appear that combustion was more complete with warm air, and that over 20 per cent. more of the oxygen of the air is abstracted in warm weather, (temperature not given)]. It was shown that " while sudden changes of temperature cause immediate variation in quantity of carbonic acid, a medium degree, as of 60°, is accompanied by all the variations in the quantity of carbonic acid, and that there was no relation between any given temperature and quantity of carbonic acid at different seasons. Whatever was the degree of temperature, the quantity of carbonic acid, and all other phenomena of respiration, fell from the beginning of June to the beginning of September. Atmospheric pressure had no influence on seasonal or other changes. The exertion of walking two miles per hour induced an exhalation of 18·1 grains of carbonic acid per minute, and at three miles per hour of 25·83 grains. The effect of the tread-wheel at Coldbath Fields Prison was to increase the quantity to 48 grains per minute. B.

* There are some discrepancies in the above which have come from Dr. Smith's own figures, 178 : 111, is not the same ratio as 10·4 : 6·7.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXX. DECEMBER, 1875. No. 6.

EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors, the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Governmental Requirements and Patent Rights.—In an extreme view of the rights of inventors, many people almost lose sight of the tenures under which monopolies formed by *letters* patent are held; that such (so-called) patents are grants or gifts justified solely by public policy, in the encouragement and accomplishment of novel industries and arts, and limited by statute in various ways, especially in duration of holding. Beside the statutory limitations, there are common law ones founded on the older English jurisprudence. Thus, no *patent* could be supported in any of our courts in restriction of the right to use an implement of warfare, or to use any other invention needed by government for any of the purposes of defense or armament, the patented object occupying the same position with other private property, namely, that of subserviency to the exigencies of the commonwealth.

The *right* of ownership to an invention, in the strict sense of right, is an exceedingly slender one. In this country, it attaches to original invention only (the fact of accomplishment not having due force as yet in our legal decisions) while generally, elsewhere, introduction combined with novelty is requisite.

Every child invents anew and originally all the processes of daily life, from the combination of the hammer with the looking-glass (if chance gives him possession of these coveted objects of childhood) upwards. Every schoolboy of aptness in mechanical application, invents from the description of his books, apparatus and contrivances in advance of his lessons. In fact, the chief interest in his studies is found in the excitement of application they suggest. Every apprentice in the workshop, who ever comes to be a workman, invents at least one steam engine or loom, explores a perpetual motion, and constantly finds new ways, to him, to perform what he sees going on about him, or what he is called upon to do for himself. The practical workman is no better off in his field of invention. Each skillful process which he accomplishes, beyond the bare skill of manipulation in regular task work, is an effort of invention; frequently, it may be said generally, exceeding in merit the greater number of those which bring (un-) merited rewards in the lottery of the patent office.

There comes a pang of regret to every draughtsman or mechanic, when he finds his thoughts and labors have been anticipated and possibly excelled by others. The student, the philosopher, or the literary man experiences the same, on coming to the knowledge that he has burnt the lamp, solved the difficult problem, annunciated the labored thought, and that others more comprehensive, more ingenious, or more eloquent, have beaten the paths, until, perhaps, not a stone is left upon them, or even a spear of grass to be trodden down. The mechanic is less fortunate than these, not only,

> "But knowledge, to their eyes, her ample page
> Rich with the spoils of time, did ne'er unroll;
> Chill penury repressed their noble rage,
> And froze the genial current of the soul."

But the "ample page" records only a very little of the practice, and explains yet less of the theory of his vocation. The professor or the book-writer have far more to learn from the workman than the workman from them. It is an unsatisfactory comment on the relationship of the workman and the inventor, to knowledge, and to the adminis-

tration of our patent laws, that the less a man knows, the more he can patent.

The evident limiting consideration of *right* to invention altogether, lies in the certainty that any and all inventions of value will be invented by some person at some time when circumstances and time develop the necessity. In fact, the settlement by our courts to-day, of the claims of patentees whose inventions (?) have just come to fructuation—inventions which have been matters of record in advance for years, decades, centuries, and in instances of actual occurrence, for millèniums, but have failed to have common usage of to-day, for want of requirement in our dark ages, is one of the knottiest problems of special pleading, calling for the most ingenious of expert perjury.

If it were not to a thinking man a very painful exhibition of futile aspirations, it would be amusing to listen to a patentee, the tenure of whose patent rests upon the accident of the presumed first application of a common device, discourse on thieves, pirates, highway robbers, when one knows that the least investigation into the practice of those who have filled similar requirements elsewhere, will develop that fatal want of originality, before which the *right* will disappear, and "leave not a rack behind."

The most enthusiastic inventor and patentee recognizes that his right must and should terminate as certainly as his own life. He knows that his own invention is founded upon prior ones, innumerable; and immeasurably more important. He can have his apple and eat his apple, and it is gone, but the seed is the property of mankind. The patent rights of Tubal Cain have ages since expired. However unwillingly the concession may have been made, the inventor acknowledges some common claims of mankind to the industries and arts of ages, only claiming a superiority, not probably in actual *knowledge* of all that has been done before him, but in perception of mechanism, since the world began.

The manufacturer is more willing to deny the ideal or inventive property, and is often dubious whether his industry, capital, or good-will, either earned by perhaps a lifetime of work and care, or inherited from previous earnings, ought of *moral* right to be supplanted or destroyed by the changes of some small, but essential detail of his processes of work; still, with restrictions as to duration, he may, on general grounds of development and growth, assent to patent rights,

trusting that he may secure to himself the advantages of the resulting monopoly, or at the worst show such fight as will eventuate in a share of the spoils.

The community as represented by the government of the land (for the press representation is subsidized by advertisements completely to the patent interest), has not very fully weighed the two sides of the question, but has decided for the present that if any need of art or industry occurs, the first claimant shall have an exclusive right against all others, for the magical number of seventeen years, regardless alike of the obvious nature of the claim, and of any effort to introduce or develop a result. And having thus established a legal patent right, on the same grounds that public defense may require the use of articles or processes covered by patents, the public welfare does (or may be assumed to) demand, or at least make it desirable to require, that private citizens shall in some cases use things patented.

One of the primary duties imposed upon Congress by the constitution, is the regulation of commerce, not that the duty of a supreme government is derived from the constitutional stipulation or covenant, but that by this delegation of authority, Congress is elevated to a supremacy of government. The performance of this duty, the protection of persons and of property, the collection of revenues, and the expenditure of the same, calls for enactments, general and special, to satisfy all and each undertaking, or dereliction which may be incident to the traffic of the nation. If Congress finds in the course of legislation, there is known to exist any one article or process calculated to facilitate commerce, or protect the traveler or property in transit, to secure returns to the treasury, or in otherwise be exigent to the country, then the *right* to require the use of such article or process, patented or otherwise, is a foregone conclusion.

Whether the patentee, either by absolute refusal, or by establishment of excessive or any values, possesses a *right* to prevent the fulfilment of the law, would seem a question equally easy to decide, and it becomes eminently proper to consider in what way an enforcement of legal requirement can be made without hardship to the patentees, or burden to the user.

There are two points of view from which to look at these questions. The *first* one is founded on the absolute rights of the community in contradistinction to *grants* to patentees. A man cannot lose that which he never had. If it be enacted, that in all future grants of

patents, the public right of usage, manufacture and sale, for any specified purpose of governmental requirement, by law, shall be reserved as free and common to all citizens, the question is decided for all time hereafter. This simple, radical and effectual remedy is not offered here as the advisable, or perhaps the entirely equitable course to be pursued, but it can be affirmed to be more fair and liberal to the patentee than has been or is his course to the government or community on the opposite side of the transaction. The nation can afford to be generous and liberal in its dealings with inventors, and even if the course of law should be modified as above, the claim of real merit is certain to be heard. A public benefactor, who has earned a public reward, is sure to receive it.

This course, however, may be somewhat at variance with the adopted policy of the nation, and the *second* aspect of the case may be more favorably regarded. The necessity of laws enforcing the use of patented articles or processes by private individuals, having been admitted, the public right to require a surrender, in some senses, of the patent grant, is consequent, and in continuation of the argument, it would seem that public expenditure ought to commute the damages to the patentee. In other words, if it be required by law to use or provide anything, the manufacture, sale or usage of such thing shall be free and unrestricted for the required purpose ; and if the requirement involves the deprivation of any private rights, they (the rights) shall be satisfied by public compensation ; or, on the other hand, if the requirement involves the resumption or restriction of any grant, wholly or in part, the right of resumption or restriction for these purposes shall be one of the understood conditions of the original grant, and the equitable value of that portion of the grant resumed or restricted, shall become a claim against the United States, to be settled by action in the Court of Claims, in the usual course of procedure in that court.

This final proposition, that government should restrict its original grant, and assume full ultimate consequences of any loss in its pecuniary aspect, may be novel, but it is thought that a consideration of its effect upon the three parties interested, will exhibit advantages to each, and demonstrate itself to be a more equitable solution of the problem than has been before offered. Let it be a condition (in emendation of the patent laws), precedent to all future grants of patents ; of the retention of the right of government *for* its own purposes, or *for* lawful requirement of use, to free the manufacture, sale

or use of the thing wanted or required; and although it may be inferred from what has before been said in this paper, that government already possesses the right to limit or restrict a patent now in existence, when it is deemed sufficiently necessary to the public welfare or service to require its public use, it will be better possibly, to provide on articles now patented, that such public use shall not be enforced until the patentee relinquishes his claims of monopoly.

With these principles of law firmly established as a ground of action, a committee of Congress can enter upon a comparatively unbiased consideration of the mechanical means available for the protection of life, of property, or the attainment of any of the ends of commercial or national legislation. The proposition or the counsel of the engineer or scientific man will once more have weight in determining the laws. It will cease to be for the interest of mere speculators, to fasten (like leeches) on commercial transactions which Congress may be called upon to regulate or control. And although a perfect system of laws may not immediately result, at least one cause of very bad laws will be removed.

The effect on purchasers and users will be singularly grateful. That the burden and cost of public requirement for the public good will have been removed from the shoulders of the few, will be fully appreciated. But even this burden has not been the most onerous or annoying. What has been specially vexatious, has been the foolish, unnecessary requirements foisted upon some of our greatest commercial interests, under pretext and color of promotion of the public welfare. Take, for instance, the steamer laws; it may be safely affirmed, that to this present time, the patent system has not produced any invention reducing materially the insecurity of the boiler, and from all the attachments demanded by law, which may have been attached, there has only resulted a reduction of the responsibilities of the firemen, engineers, or *owners*. The Tice Meter is a case in point, keenly appreciated by the distillers. The hardship of having an arbitrary, fictitious value set upon an article of necessity, is one of the least of tolerable ones; and patent owners have not been reluctant to take advantage of their right.

In this matter of protection of commerce, the interest of the common carrier is identical with that of the public. Competition for price might occasion some disregard of safety, but a universal requirement puts all competitors on the same level of expenses, and

the belief that enactments are for public good, and not for private advantage, will associate on a mercantile basis, as well as upon the sentiment of justice; those who are to be governed by the law, with those who make the law, in one quest of the best, most lasting, most suitable for the intended purposes.

In the bidding for government contracts for the supply of patented machines or apparatus, a competition under the system proposed will become a reality, and an advertisement for proposals something more than a farce. Whatever mistake or absurdity may attach to all government proposals, from indiscriminate bidders, there are none so great or ridiculous as those for what only one person can supply; and generally it may be said *he* never takes the trouble to respond. Certain of his sale, and of the government purchase, the patentee allows others to bid at any rate they may get, and sells to the fortunate competitor at his fixed price, avoiding the odium attached to a contractor; and superior in his honesty, when that contractor has been found out in obtaining a merchant's profit.

But to the patentee the new plan offers a positive reward. Very little of the proceeds of any sales made in accordance with the law has ever reached him. It is the rarest case where the patentee is the manufacturer or even the licenser in receipt of a fair royalty. In the incipiency of the proposed law, he will, he must have parted with most, if not all, his interest for lobby and generally fraudulent demands. Speculators will have preyed upon him at every point. An advertising notoriety must have been attained at great cost—testimonials have been manufactured—scientific evidence *prepared*—rival claims settled, these latter being more formidable in proportion as his own invention was more meritorious; and, finally, after the traveling expenses, cost of dinners and suppers to worthless men in Washington, etc., etc., have been defrayed; the inventor's share, *the reward of* GENIUS, will have dwindled away, almost to the status of his claim for novelty. Under the new plan, on the other hand, if it shall be evident that an invention will so fill a public requirement as to justify adoption and compulsatory use, the claim of the inventor will follow the course of all just unsettled claims against the United States. With suitable and special provision he, and he alone, can obtain payment; the amount of which will be fixed and established by judicial evidence before a competent tribunal; and the final reference to Congress, in appropriation, will complete the protection of the treasury, to the satisfaction of the most economical reformer.

The Water Commission.—In accordance with a request, the following recommendations of the Commission of Engineers on the water supply of Philadelphia is here published in full for the benefit of the readers of the Journal.

Recommendations.

These may be considered in two parts; those relating to the more immediate requirements of the city, and those which belong mainly to the future. Among the former are:

1. The completion of the East Park Reservoir, and connecting it by 48-inch pumping mains with the works at Spring Garden and Fairmount, and by distributing mains of the same size with the Spring Garden, Corinthian, and Delaware Reservoirs.
2. The improvement of the machinery at Fairmount, and the building of two improved turbines.
3. The erection of a pumping engine of 10 million gallons capacity at the Spring Garden Works.
4. Re-arranging the pumping mains at the Belmont Works, and putting in a proper distributing main from Belmont Reservoir to supply the east side of the river.
5. The building of an intercepting sewer on the east side of Fairmount Pool, or of a conduit for purer water from Flat Rock Dam to the pumping works at Belmont, Spring Garden, and Fairmount.
6. The extension of the inlet pipe at the Kensington Works into deeper water.
7. The raising of the Delaware Reservoir six feet.
8. The establishment of a new pumping station at Lardner's Point, with a reservoir at or near Wentz Farm, with proper mains connecting the pumping works with the Delaware Reservoir, and with the new reservoir supplying Frankford, etc.
9. The consideration of the purchase and use of water-power at Manayunk, and the construction of the proposed new works dependent thereon.

It is not expected that all of these will be finished in 1876; but enough may be accomplished to improve the quality and add to the quantity of the water supply during the Centennial year.

The completion of them all would both increase the quantity and improve the quality of the water supply of the city, to a very great extent.

Provision for Centennial Year.

To provide for the Centennial year we recommend the immediate completion of the alterations and improvements of the present wheels at Fairmount; the erection of a ten million engine at the Spring Gar-

den Works; the extension of the inlet pipe at the Kensington Works; and the completion of the East Park Reservoir and its connecting supply and distributing mains.

And in view of the delay in building an intercepting sewer, the discharge from the breweries and the sewage in the vicinity of the Spring Garden Works should receive immediate attention.

In regard to the future, our investigations show that there is only one of the proposed plans for bringing water from a distance which seems to be reasonably practicable, namely, the Perkiomen Reservoir and Conduit scheme, as presented in this report. The proper time for entering upon a work of such magnitude, requiring so large an expenditure of money, will necessarily depend in some measure upon the action of Councils on the subject of the works we have recommended to their consideration, and also upon the success which may be met with in maintaining a satisfactory supply of good water by the means we have indicated.

Raising Fairmount and Flat Rock Dams.

It has been suggested by Mr. James F. Smith, Chief Engineer, in his paper contained in the appendix, that the dams at Fairmount and Flat Rock might be advantageously raised, and we commend this subject to the consideration of Councils.

Science and Art at the South Kensington Museum, London.—A circular issued by a committee of the most eminent men in the different branches of science and art, gives notice that a Loan Exhibition of Scientific Apparatus will be opened at the Museum on the 1st of April, 1876, and remain open until the end of September, after which time the objects loaned will be returned to the owners. It will consist of instruments and apparatus employed for research, teaching, illustration of progress of science or application to the arts, etc., etc. As far as practicable, arrangements will be made for explaining and illustrating the objects which may be exhibited, and their purposes. The cost of carriage of all the objects selected for exhibition, will be defrayed by the Science and Art Department. The entire range of mechanical or physical application is covered by the prospectus of the committee, which can be seen on the tables of the Franklin Institute, together with forms and other information for those who desire to exhibit.

THE EFFECT OF ELECTRIC FORCE ON THE MATERIAL OF STEAM BOILERS.

Dear Sir:—In the November number of the Journal, which has just reached me, I have been attracted by your note on page 345, following Dr. Cresson's paper "on the effect of magnetic and galvanic forces upon the strength of, and destruction of iron and steel structures." The notion that the destruction of iron boilers by corrosion when supplied with ordinary water is ascribable to galvanic action, has, in my opinion, very little foundation in fact. Some samples of iron corrode more readily than other samples, but they will do so when submitted to any of the conditions favorable to such slow combustion. In my experience as a locomotive engine builder and more recent observations I have never seen any good reason to abandon the common practice of uniting metals of known different electro-conditions in one structure, and will cite what you must have overlooked as you do not mention it in your note, viz.: the use of cast iron boiler heads, cast iron man-hole rings in connection with wrought iron shells. Also in locomotive practice of wrought iron boilers with copper tubes, and even copper fire boxes. Some such boilers being of undoubted long life. So with many instances of boilers with brass tubes and all the fittings such as hand hole plugs are made of brass. I imagine that any of these metals so placed in connection with one another as to form a galvanic battery of usual construction, and then immersed in a bath of such water as is usually used in boilers, that the electric or galvanic currents obtainable from such, a construction would be a very feeble and that no "strong galvanic action" would take place. I like to see all theories substantiated by facts, but the facts should be viewed equally not unequally. Electricity is dragged in too often to account for phenomena that could be explained in other ways. You are quite right in saying that "it is a serious mistake to admit as a popular utterance, that we must look to 'galvanic (voltaic ?) force' as the *cause* of deteriorations of boilers, or of iron structures of any kind." I do not wish to say that it has nothing to do with it under certain conditions, but that it plays any such important part as to make us avoid combinations of metal of great mechanical advantage when combined, for fear that some grand galvanic action will destroy the structure so built up, when we all know well enough that such combination of dissimilar metals have stood the test of years, and will continue to be used with safety in good engineering practice.

3301 Baring St., Nov. 5, 1875. Coleman Sellers.

Errata.—It will be noticed that the number of this Journal on the cover is 600 in place of 599, in (regular sequence). There was an error committed in August and September, 1870, both of which were numbered 536, and this correction is now made so that the next year shall commence properly, number 601, there having been 600 numbers actually completed by this present one.

Correct page 358, lines 21 and 22, for A,—A,—A, read N,—N,—N.

Franklin Institute.

Hall of the Institute, Nov. 17th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers in the chair.

There were present 227 members and 7 visitors.

The minutes of the last meeting, held October 20th, were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their meeting, held on the 10th inst., the following donations were made to the library:

Report on the Water Supply for the City of Philadelphia, made by the Commission of Engineers appointed by the Mayor, under the ordinance of Councils, approved June 5th, 1875. Philadelphia, 1875. From Solomon W. Roberts.

Laws governing the steamboat inspection service. Revised statutes of the United States. Washington, 1875.

General rules and regulations prescribed by the Board of Supervising Inspectors of steam vessels, and approved by the Secretary of the Treasury. 1875.

Proceedings of the Twenty-third Annual Meeting of the Board of Supervising Inspectors of steam vessels, held at Washington, D. C., January, 1875. Washington, 1875. From Messrs. John Menshaw and F. L. Hand.

Ingeniors Foreningens Forhandlingar. 10 Vols., 1866–1875. From the Society, Stockholm, Sweden.

Report of the Director of the New York Meteorological Observatory in the Central Park, for the year ending December 31st, 1873. From the Director.

Circular of Information of the Bureau of Education, Nos. 3--6. 1875. From the Bureau of Education, Washington, D. C.

Report of the Committee appointed by the Board of Public Education to inquire into the sanitary condition of the schools of the First School District of Pennsylvania. City of Philadelphia, 1875. From Louis Wagner, Chairman of Committee.

Proceedings of the Philosophical Society of Glasgow, 1874–5. Vol. IX, No. 2. From the Society.

The Actuary also reported that in accordance with the recommendation of the Committee on Science and the Arts, the Board of Managers have awarded the Scott Legacy Premium and Medal to Job A. Davis, for the vertical feed as applied to the Davis sewing

machine; to Sholes & Gliddens for improvements in type writers; and to B. Tatham and J. M. Brittin for their safety catch for elevators.

Also the following resolutions adopted by the Board:

Resolved, That the Silver Medal of the Institute be awarded to the American Meter Co., for their Jet Photometer, in accordance with the conditional recommendation of the Judges of Class 29–15 of the 27th Exhibition.

Resolved, That the Actuary report a vacancy in the Board of Managers caused by the resignation of Prof. Geo. F. Barker from the Institute.

Dr. W. G. A. Bonwille read a paper on the use of "air as an anesthetic."

Some remarks on Dr. Bonwille's paper were made by the President and Drs. Collins and Mills.

The Secretary gave a description of the alterations recently made to the Connecting-Railway bridge, which was illustrated by a number of pictures projected on the screen.

There were also presented and described Heyl's wire book-stitching machine; Hubert's patent roofing; Spinney's patent fuel, and J. C. Bryan's lightning rods, weather vanes, etc.

Mr. Coleman Sellers offered the following preambles and resolution, which were unanimously adopted:

WHEREAS, The Franklin Institute learns that a steam street car has been built by the Baldwin Locomotive Works, and will, in a few days, be ready for trial, and that the Baldwin Locomotive Works has applied to Councils for permission to try the same on some of the street railways west of the Schuylkill; and,

WHEREAS, In the opinion of the Franklin Institute, it is of importance, not only to the manufacturing interests of Philadelphia, but to the community at large, that proper encouragement be extended to an experiment looking to the substitution of a more desirable motor than horse power for the propulsion of our street cars; therefore

Resolved, That this Institute respectfully request Councils to grant the permission applied for, under such restrictions as they may deem necessary, and that copies of these preambles and resolution be presented to to the Select and Common Councils of the City of Philadelphia at their meeting to-morrow afternoon.

The following preamble and resolutions were offered by Mr. Hector Orr, and unanimously adopted:

WHEREAS, To the array of our departed members for this year, we must now add the name of Horace Binney, who continuously

through three generations in Philadelphia has stood as our foremost citizen for many years. Therefore be it

Resolved, That we respectfully here express our appreciation of his worth as a citizen and legislator, and a hearty, though unobtrusive friend of the Franklin Institute; who bore his high faculties without pretension and never misapplied them; whose counsels are a legacy more valuable than gold, and whose example is better than both.

Resolved, That these proceedings be communicated to the family of Mr. Binney and be engrossed in full on our minutes.

Mr. Washington Jones called attention to the notice of a vacancy in the Board of Managers and nominated Mr. Chas. H. Cramp for the position.

On motion, the Institute went into an election, and the Chair appointed Messrs. Coleman Sellers and Chas. S. Close tellers.

The tellers reported more than a quorum voting for Mr. Cramp, and none against him, whereupon, Mr. Chas. H. Cramp was declared elected a member of the Board of Managers, to fill the unexpired term of Prof. Geo. F. Barker.

Mr. W. B. LeVan presented the following, which was adopted:

Resolved, That the Committee on Publication of the JOURNAL OF THE FRANKLIN INSTITUTE be requested to consider the propriety of inserting in each number, on the first page, the following: NOTE.—The Franklin Institute is not responsible as a body for the opinions advanced in its publications.

On motion the meeting adjourned.

J. B. KNIGHT, *Secretary.*

Alterations to the Connecting Railway Bridge and its Foundations.—At the stated meeting of the Institute in November, the secretary gave the following account of these alterations, illustrating them with several views, projected on the screen.

This bridge, which spans the Schuylkill river in the city of Philadelphia, a short distance above Girard Avenue, was opened to travel in 1867. It is of iron, of the Pratt truss system, originally 265 feet in length, carrying the track upon its upper chord. The approaches are of masonry, and consist of a series of semicircular arches of 60 feet span, supported on piers of varying height, those forming the abutments, and carrying the iron superstructure, being 42 feet high, and reaching 10 feet below the surface of the water, where they rest on foundations built of timber crib work, filled in with broken stones and cement.

On attempting to remove the centres on which the arches were constructed, and before the iron span was put in place, it was found that they would not stay up, but thrust out at the haunches. The iron span was then put in, with the hope that its weight would resist the thrust of the arches, and which it did do in a measure, but the masonry still moved, and to such an extent that it pressed against the lower chord of the bridge, and buckled it up in the end panels.

An arch of cast iron was then put in the bridge to counteract the thrust from the masonry arches, and this not proving sufficient, a second or upper arch was put in. These were not attached to the bridge, except to stiffen and keep them in place. In this condition it came into the possession of the Pennsylvania Railroad at the time of leasing the New Jersey Railroads.

In 1872, Mr. Joseph M. Wilson, Engineer of Bridges and Buildings, Pennsylvania Railroad, was requested to make an examination of, and report on this bridge, which he did, and afterwards took charge of it.

It was found that with the weight of the iron span, and the resistance of the iron arches, the masonry was theoretically stable, yet was slowly but surely disintegrating under the varying resistance due to the expansion and contraction of the iron arches from changes of temperature.

A variety of methods for remedying the difficulty suggested themselves, but the only one considered feasible was to go down to the bed rock of the river in front of the piers supporting the iron span, and build up additional masonry, connecting it to the old, and shorten the superstructure by one panel at each end, change the end posts, and remove the iron arches.

To do this, the pier was surrounded with a 16 sided coffer dam, 66 feet in diameter in the clear, on top, built of 12 inches square timber, placed horizontally, and having an inner and an outer shell, the space between being 6 feet at the top and 10 feet at the bottom, and which was filled with loamy gravel puddle.

The rip rap around the abutment piers in the way of the proposed dam, having been dredged out, and the bottom cleaned as well as practicable by divers, the coffer dam was first framed and put together on shore, the bottom edge, cut to fit the profile of the rock bed of the river, and then taken to pieces, and erected in place.

Short vertical pieces of plank, sharpened wedge-shape at their lower ends, were then nailed to the outside of each face of the dam, being

well driven down to the rock to make a tight fit. The spaces between the rock and timber were then calked with oakum by divers, and filled in between with cement, after which the puddle was put in place.

To remove the leakage of the coffer dam, pumps were provided, with a capacity of 4000 gallons per minute, but only about one-tenth of this was required, as the actual leakage as nearly as could be ascertained, did not exceed 400 gallons per minute. The remainder of the rip rap, in the interior of the dam, was then removed, and the rock reached at a depth of about 32 feet at the east, and 37 feet at the west pier, at the lowest point.

The rock was carefully cleaned off, and the new masonry built from it, being about 15 feet additional; the old pier being 12 feet at the spring of the arch, 15 feet at the base, and 17 feet at top of crib foundation.

The iron arches were then taken out, the bridge shortened about 13 feet at each end, the end posts being moved in one panel, and the entire work is now completed, with the exception of a small portion of the railing on top, all having been done without any interruption to travel, and being in every way an entire success.

The work was in charge of Mr. Wilson, as stated, but was executed under the immediate superintendence of Mr. Stacy B. Opdyke, Jr., Assistant Engineer, Pennsylvania Railroad.

The contractor for the coffer dams was Mr. Jonathan Powell; for the masonry, Messrs. Smith & McGaw; and for the changes in the iron superstructure, the Keystone Bridge Company, by whom it was originally built, from designs by J. H. Linville, Civil Engineer; but it is proper to state, in this connection that the original errors in the construction were entirely connected with the masonry, which did not come under Mr. Linville's charge. K.

The Market Street Bridge.—The superstructure of the Market Street Bridge over the Schuylkill, was entirely destroyed by fire on the afternoon of Saturday, November 20th. The bridge was originally built in the year 1800, by a private company, and replaced a floating bridge of previous existence. It became the property of he city of Philadelphia (prior to the consolidation) in the year 1840; and the superstructure was entirely reconstructed in 1850. The abutments and piers are as they were first built, and are said to have had a foundation upon the solid rock; that of the western abutment

being 41 feet below the level of ordinary high water mark. The three spans are 150,—194,—150 feet, clear of abutments and piers.

The superstructure which has been burned, consisted of three spans of timber framing, composed of arches, combined with "Burr" truss work, and was built with every care to make it substantial and *permanent;* and it was subsequently further strengthened by the Pennsylvania Railroad Company, when they acquired the privilege of using the "city track;" until it was one of the strongest bridges in the country. The whole was covered by a wooden roof, with tin outer covering, forming altogether an immense mass of dry wood work.

An averment has been made by a person who purported to be an eye witness, that exactly twenty-seven minutes elapsed after the flame appeared (which was simultaneous to the discovery or alarm); when the first span fell, the second followed instantly, and the third at an interval of four minutes.

The traffic upon this bridge had quite surpassed its capacity, and the necessity of enlargement and reconstruction had become apparent, and the opportunity now given to accomplish this purpose, is in some way a ground of reconciliation for the loss. It is to be hoped that this opportunity will be suitably availed of, and that the new structure will combine excellence with architectural effect; a combination not completely attained in some of the bridges over the Schuylkill.

Bibliographical Notice.

The New Method of Graphical Statics. By A. Jay Du Bois, C. E., Ph. D. Reprinted from *Van Nostrand's Engineering Magazine.* New York, 1875. D. Van Nostrand.

While it is not quite correct to call this method a new one—the students of the Ecole Polytechnique of twenty years since were made conversant with most, if not all, the applications set forth—we presume it will prove really novel to general students and readers in applied mathematics, and especially to many practical engineers. Any process which avoids, or eliminates, or corrects errors of computation, is of great importance; and this one, which accomplishes all these and besides gives a general solution to problems, when figures only offer particular ones; should be made familiar and ready of application. The printing of figures in the text, in place of in separate plates, would have added much to the convenience of those requiring the book for reference, but this deficiency will be overlooked in its usefulness: and in its shape of a separate treatise, the work should form one of the books of an engineer's library.

Civil and Mechanical Engineering.

THE PRODUCTION OF TRULY CYLINDRIC SURFACES FOR CALENDER OR OTHER ROLLS.*

All mechanics who have had many years' experience in the workshop, have learned that the most accurate result of turning fails to give either parallelism or concentricity to a cylinder. Only a relative perfection of the lathe in all its parts, an almost accidental homogeneity of the material upon which the turning is done, a fortunate endurance of the tool used on the work, and much skill of the workman allows even an approximate cylinder to be made. The admitted conclusion of the mechanic is that following the turning, and after as good work has been done as will proceed from average lathes, tools and workmen, the rolls must be finished by a grinding process. The method of trueing the surface of a cylinder by grinding wheels (stone or emery) mounted on a carriage traveling on the ways of a lathe, in which lathe the roll is hung, either on centers or on its own bearings, is well known, but this process is so embarrassed by the imperfections of the lathe ways (either original or in wear) by the spring of the roll away from the grinding wheel, and by the necessity of great accuracy in setting the roll parallel with the ways, that the production of a perfect roll becomes almost impossible. After attaining a degree of perfection in this way, the workman has found the grinding of two rolls together, with a slight vibratory motion to one of them, to be the best way to correct the errors of diameter, and straighten their faces. And after all, much labor, skill and care has failed to satisfy the critical workman, and only produced calender rolls for paper machines that have sufficed for, rather than answered the requirements.

* A previous description of this method, with a cut of the machine, will be found in Vol. lxi (3d series), page 392, but as it was not thought by Mr. Poole himself (the compiler of the description), to be sufficiently clear and definite, the present paper has been prepared. It is proper to add, that the author of the present paper was not aware of the existence of the previous one until after the completion of his article, ready for the press; but a comparison of the two papers has led him to conclude that the second one may prove instructive.

There was shown at the recent exhibition of the Franklin Institute, by J. Morton Poole & Co., of Wilmington, Delaware, a paper calender, having eleven rolls. The rolls were 7 feet in length, measured on their true faces, the top roll being 12 inches, followed by eight rolls of 7 inches, one of 12 inches, and a bottom roll of 15 inches diameter. These rolls were, all of them, as far as possible callipering and examination would detect, *perfectly* parallel and concentric, and would bear the exacting test of the perfect visual contact when interchanged.

The machinery for production and finishing these rolls being protected by patents held by Mr. Poole, he has willingly exhibited it, and a brief description of the principle involved, and special apparatus employed, will be of undoubted interest to the readers of the JOURNAL.

Any person wishing to find if a shaft or roll is round or is parallel, would try it with a pair of callipers. This is *all* that Mr. Poole has done. Only that he has mounted at each toe of the *callipers* an emery (corundum) wheel, and these wheels grind the spot they touch, to the desired uniform calliper. The roll being mounted in a lathe, the *calliper* wheels (one on each *side*) are passed down it *on the line* of the centre (or very close to this line) whilst it revolves.

Any machinist will see that if the line of the centre of the roll in this supposed case is exactly in the plane of the path of the axis of the grinding wheels, the result, after all requisite grinding is done, must be a perfectly callipered roll (and this is also true if the line of the centre of the roll is parallel to, above or below, the plane of the path of the axes of the grinding wheels.) But then this may not, therefore, be a round one. A cardioid or heart shape cam, or an eccentric will calliper perfectly, and yet not fulfill the requirement of cylindric perfection. Now, if we consider the *callipers* to hang freely, it is evident that if they are grinding an eccentric or cardioid shape, they will oscillate to follow the eccentricities. If, therefore, the *callipers* are held from swinging by friction of sufficient amount to make one of the two wheels do all, or most of the work, the high place of the eccentric or heart will be reduced first on one side and then on the other, and when a reduction is once provided for, it is only a question of time when the object will become *perfectly* round.

The great interest which attaches to Mr. Poole's system of grinding is in the close approximation to mathematical accuracy resulting from it, in the production of *original* cylinders, cylinders which in no

respect follow or repeat inaccuracies of their own, or even of the machine used in finishing them, and so nearly fill the requirements of exactness that eight or ten can be selected from a thousand, and piled into a set ready for use. It is not essential that the finishing (grinding) lathe shall pretend to much accuracy in construction, for it is incomplete unless the roll to be ground is in place. *The roll itself forms part of the machine*, and its axis of rotation is the real guide for the path of the callipering grinding wheels.

To make this condition better understood, let it be conceived that at any place the callipering wheels are stopped from traversing along the ways of the lathe bed, and operate upon a portion of the roll that is decidedly eccentric from fault in turning. At this point of the roll, the grinding wheels acting as callipers, will vibrate back and forth (crosswise to the roll), moved by the eccentricity; but from the resistance to this motion given by clamping them, they will cut hardest on the high sides, and the force required to vibrate the callipers will in time wear down the eccentricity, and a true circle be the result. What has thus occurred at one point on the roll surface, will be repeated by traversing the grinding wheel for its entire length, and the finished roll becomes the mere extension of the true circle into a cylinder. Thus the grinding lathe *originates* an absolute cylindrical form without the aid of straight-edge or guiding former-bar.

The condition of this accurate grinding was stated to be the coincidence or parallelism of the axis of the roll with the plane of the path of the axes of the grinding wheels. If the roll is placed much out of this plane, it will be noticed that the callipers will only measure the diameter at the point where it coincides with the plane, and that anywhere else they measure above or below the centre. If the point of coincidence of diameter be the middle of the roll, the shape resulting is dice-box form (a hyperboloid of revolution) and in fact this very shape is produced sometimes intentionally, as in the case of chilled rolls for sheet iron, which require to be a little hollow in the middle to compensate for the greater expansion of that part by the heat, when rolling iron. But if the roll so nearly coincides, that the variation of the line of the axis of the roll with the plane of the path of the axes of the wheels (or a plane near to it, but parallel with it), bears but a small proportion to the diameter of the roll, the error in true cylin-

drical form becomes exceedingly small.* If a roll 10 inches in diameter is assumed, and if the grinding wheels be taken to be 8 inches in diameter; and if the roll be placed in the grinding machine 1-10th an inch out of the proper position, (supposing in this case the middle of the length of the roll to be in the right plane and the ends 1-20th an inch up and down) the diameter at the end of the roll will exceed that of the middle by 1-6480th of an inch.

Now it is perfectly feasible to set a 10-inch roll within 1-50th of an inch, and the inequalities of the ways of a bed arising from wear ought to be kept within this limit, and if 8-inch grinding wheels are supposed, the practical accuracy following this setting would be within 1-162000th of an inch. The sag of a roll (for they are ground in horizontal position) from its weight alone is an estimatable quantity, is so small in rolls of ordinary proportions that 1-2000000th of an inch would include the error in parallelism proceeding from depression from proper plane in the centre, for a roll 8 feet in length.

The effect upon the trueness of the cylinder of setting the roll in the grinding machine, out of the line of the ways or path of the callipering wheels, but in the proper plane, is nothing whatever, within large limits of deviation. After the roll is rounded by grinding, it is obvious that it makes no difference how the callipers move, only provided the points of contact with the cylinder be on the diametrical lines; and even when rounding up with the callipers held by friction from freely placing themselves, the oscillatory movement of the callipers continues so long as any eccentricity exists, after which the calliper movement becomes steady, and the friction resistance transfers the grinding work mainly to one wheel, when the traverse is in one direction and to the other on the return. It is only necessary that the friction nip should not relieve one wheel entirely, and it is of course best, after the roll is truely round (a condition easily detected by the marks on the face left by the wheels) to complete the finish of the surface with free *callipers.*

The small errors indicated as possible to this system of grinding

* The error resulting from want of parallelism of axis of roll with the plane of the path of callipering wheels is, (neglecting the square of the error as inconsiderable) at any part above or below the normal plane =

$$\frac{\text{Twice the square of } \left\{ \begin{array}{l} \text{elevation or depression, multiplied by diameter of the roll} \\ \text{divided by the sum of diameters of roll and one wheel} \end{array} \right\}}{\text{divided by the diameter of the roll.}}$$

with but a minimum of care in setting can be nearly eradicated by excellence in workmanship, and Mr. Poole does actually work below the limits here stated.* Admitting an error of a 50000th part of an inch to exist, and to be distributed (by a uniform deviation out of plane) into the surface so as to give the hyperboloid before spoken of; admitting this, the contact of a set of rolls would still be perfect, for the error is far within the elasticity of the material of the roll, so that a set of nine rolls thus ground, would have line bearings on each other of apparent perfection.

In fact, the lower roll of a set in a calender cannot be ground entirely by this system; for it has to carry the weight of the entire set, and of itself, and is depressed to a catenary form. The material of these rolls under their own weight can be considered as perfectly elastic and the pressure will then be that of a fluid of uniform depth upon the *string* support. It has, therefore, been found necessary to produce a barrel shape roll for the bottom one. The amount of enlargement in the central diameter for a six feet by fourteen inch roll is stated by Mr. Poole to be about 1-150th an inch. This roll, therefore, is first trued up round and parallel by the described process, and then is barrel shaped by the usual one of a "*former-bar*" guide to oscillate one of the *calliper* legs. This former is made with perfect accuracy, as compared to one planed up, by using a truely ground cylinder of proper length, which is laid parallel to the roll with the greatest care, and is *sprung*, by being held at both ends and forced out by a sheet of paper thickness, in the middle of its length. The accurate setting of this "*former-bar*" is ensured, if the roll is first ground parallel, by the length of the cut of the grinding wheel at each end of the roll: an indication that is measurable, in this case to a millionth of an inch. The curve derived from this distortion of the *former-bar* is not ex-

* While it is so easy for a tolerably skillful workman to set the axis of the roll in parallelism with the plane of grinding wheels, it is possible to arrange the machine so that even this care of setting may not be demanded. If, in place of hanging the grinding carriage, at both ends, from the horns of the traveling carriage, it should be hung from one end only, while the other end depends from an arm which runs or passes over the roll, and rides upon it, by a wheel (or slide) the grinding will then be done *altogether* independent of the ways of the lathe. This arrangement will therefore compensate of itself for all errors of setting, or wear or inaccuracy of ways. In such case the riding wheel (when one is used) must necessarily be very true for the attainment of absolute perfection.

actly that desired, but it approximates to it, and by the condition of nearly perfect elasticity for exceedingly small movement, as has been before stated, the two curves coincide to all needful accuracy.

The grinding machines to operate on this principle present, as made by Mr. Poole, some peculiarities of construction worthy of note. Taking for description ; the finishing machine for grinding callender rolls of from 6 inches to 16 inches diameter, and 5 feet to 8 feet in length of face. Such a machine consists primarily of a massive bed (and trough for water) much like that for a lathe of 48″ swing. Upon this bed are mounted—a driving head—two housings to take the roll necks and a carriage to travel between the housings and carry the grinding wheels. The driving head is of course out of all proportion with that needed for a lathe of similar dimension, and in fact the spindle is but 3 to 4 inches diameter, and the power is applied by a large overhung pulley without gears. This pulley is some 5 feet in diameter by 5 inches face, and is driven at about 40 revolutions per minute. [Belt power only answers to give that uniformity of motion to the roll which will produce a smoothly marked surface, for the best of cut gears leave their impression on the finished roll.] Under the spindle is placed a reversing screw gear for actuating the carriage. The mechanic will need no description of this attachment, only to say that the feed is about 3-16th an inch, and that the screw is properly shielded from drippings. The housings with their adjustments for bearings for the necks, also do not call for description to be understood by the practical man. The carriage, with what *we have called the callipers* need a more full explanation. The carriage is like that upon any lathe bed, up to the bottom of the tool post slides, but it has four posts or horns cast upon and forming part of it at the front and back corners. These posts are perhaps 12 inches apart, along the carriages, and three feet apart across it, they are **T** shape with the flat of the **T**'s towards each other, and they are not capped but the top ends are open. They are about 18 inches high. Fitted between the posts, a loose sliding fit, is placed a substantial double ended cross slide rest, which hangs, by links or knife edges, from the upper end of the posts or horns, and is free to swing from side to side across the lathe. Upon this cross slide rest at either end is mounted like tool posts, two boxes which contain the grinding wheels. Everything about this part is solid and substantial, and this arrange-

ment forms the *calliper* we have so often referred to. The *calliper* will thus be seen to be applied from below upwards—the friction which prevents oscillation is obtained by a set screw in one horn which bears on a spring washer and thus effects the *nip*.

The grinding wheels used are a special make, none having been found on sale that would fill the demand of durability so as not to wear appreciably in one travel of the carriage, and also of capability to be run with water. It being, as is well known to all grinders, impossible to get true work from a stone unless water is used freely to preserve the temperature. Corundum has proved most suitable, and the wheel-making part of Mr. Poole's establishment is by no means the least important, either in expenditure or appliances. The wheels are, when new, about 9 inches in diameter by $1\frac{1}{8}$ inches thick; they are mounted on heavy spindles with conical bearings and have pulleys to drive them, on both sides of the wheels, about 4 inches diameter by 2 inches wide. Great care is taken to balance each part of the body in rotation, separately and together, so as to get out the least jump of the grinding wheel.

The grinding wheels run with about the circumferential speed of a mile per minute. The actual reduction of a cylinder due to one pass or traverse of a pair of grinding wheels, as determined by many experiments, does not vary much from 1-20000th of an inch (= 1-40000th at each side). They are driven by *two* overhead drums, one below the other, the upper one 18 inches diameter, and the lower one 15 inches in diameter. These drums are 8 or 9 feet in length so that the belts can traverse up and down with the carriage. They are made from sheet tin, like some of the cylinders of a paper machine, and are carefully balanced at every point of their length so as to be in equilibrium of rotation. The disposition of each belt is as follows: the slack side of the belt passes down from the top drum, under the spindle pulley of wheel on front of machine, then being drawn up over the lower drum, it is passed down from the lower drum under the spindle pulley of wheel at back of machine, and finally it is a second time drawn up over the top drum to the place of beginning. The tension of a vertical belt depends upon the elasticity either of the belt (or of the shafting) and it is found necessary to drive the two drums in such way, that the surface speed of the top drum shall be just enough less than that of lower drum, as will com-

pensate for the stretch of the belt and avoid throwing all the *slackness* into the down side of the belt from the top drum, in order to ensure proper adhesion to the pulley of the first spindle. By this double loop arrangement of belts, the work is accomplished by two belts in place of four, and the contact of the belt with the spindle pulley is made 180° without using a cross belt. A cross belt is undesirable for a traveling one.

It will be noticed, that the tension of the belts tend to lift the carriage off its links and knife edges, but the weight of the carriage, with the wheels, spindles, etc., is so large as to resist this strain, and also to avoid any unsteadiness therefrom.

The arrangement of counter-shafting for driving the machine and the drums does not call for description. A copious supply of water is fed upon the roll while the grinding proceeds; this water is pumped up to a tank by a pump attached to the machine, and as the same water is used over and over, the fine corundum in suspension adds materially to the cutting effect of the wheels.

Calender rolls of greatest excellence are an American product, and depend upon our grade of gun iron produced from charcoal pig of Connecticut origin for the best, but it is probable that the product of a Siemens–Martien furnace, or possibly Bessemer material will eventually allow other iron to be used. They (the calender rolls) are now produced chilled to moderate hardness (the superlatively hard chill is blowy) with *absolute perfection*, without a pin-hole or blemish on an entire roll surface.

In turning of these rolls, exceedingly strong lathes of ordinary form are used to cut off the rising head, and true up the necks, and they are faced up in the roll lathe (of the rolling mill), which differs materially from the machinist's slide rest lathe. Both the necking and roll lathes of Mr. Poole present many features of specific excellence and novelty, but the length of this paper will not permit more than this allusion to them, except that it is proper to mention that the tool used in the roll lathe in cutting chilled iron is a flat bar of planed steel about $3\frac{1}{2}$ inches wide by $1\frac{1}{4}$ inches thick, and in lengths of from four to ten inches. The cutting edge is formed on four corners of two sides in this way: a groove a half-inch in width by one-eighth of an inch deep, is planed along the side in the middle of the thickness, and the edge (thus relieved in the centre), is ground in an ordinary parallel grinding lathe by a six-inch wheel, to the

shape or concavity of the grinding wheel. This procedure gives a cutting edge of 78°, and has been found by Mr. Poole to answer perfectly, when used in the roll lathe method of crowding up to the cut. It is however admitted that no steel is good enough, or can be made hard enough, to be so perfectly satisfactory that nothing better could be wished.

Before commencing to grind the surface of a roll, it is indispensible that the necks shall be true and round. Exact parallelism is not requisite, but the first step in roll grinding is to grind the necks on dead centres, to positive roundness. Except this is done, the *calliper* grinding of the bodies only reproduces all the eccentricities in the necks. When this precaution is neglected, the rolls will fail to drive each other without being geared together. The test of accuracy, or rather of freedom from eccentricity, is the absence from tremor when the "stack" of rolls is running. When perfect, not the slightest vibration can be felt.

It has been stated, that the action of the grinding wheels was determined to be 1-20000th of an inch for both wheels (1-40000th each). With this rate of grinding, a chilled roll of American hardness, 12 inches in diameter and 72 inches face, turned in Mr. Poole's roll lathes, with the bearings ground beforehand on centres, can be finished in seven and a half hours. To effect this, the turning must have been exceedingly accurate, and no error of callipering in the lathe, or of eccentricity proceeding from inequality of hardness of chilled surface, (or more generally from spring of the roll in cooling, which may demand a strong cut on one side, and a very light cut on the other) greater than 1-500th or 1-600th of an inch must exist prior to the grinding.

*An idea of the minuteness of the error which will prevent continuous contact of any two rolls can be entertained by referring again to the work of one grinding wheel, on one pass or traverse, equaling 1-40000th of an inch. Arrest one of these wheels anywhere in the length of a roll, and prevent it from taking its 40000th of an inch from the cylinder, and the defect becomes manifest when two

* The remarks in this paragraph are Mr. Poole's own comments, and are the undoubted result of practical test within limits of observation. The most perfect of ground polished or burnished iron surface fail to satisfy a microscope of quite low degree. The test for light was not made in a dark room, the reflection on the cylindrical surfaces brought in interferences of much complication, and the high elasticity of iron under small loads or in almost differential compression, would limit all these tests to the usual condition of *approximate accuracy*.

rolls are placed in contact, not by passages of light, but by the break in the continuity of the burnished line made by sliding one roll upon the other. When two cylinders of iron are placed together, it is just possible to detect by the eye an opening of 1-4000th part of an inch, and this minute opening separates the light into its prismatic colors. The linear contact test, therefore, becomes ten times as perfect as the visual one.

As an example of the degree of accuracy attained by this new method of grinding, the experience of Mr. Poole's machine in Wurtemburg can be cited. The government of Wurtemburg is of itself the proprietor and operator of the larger manufacturing industries (which are generally carried on by companies elsewhere), such as mining, iron and metal works, machine shops, paper making, etc., etc., and became a purchaser of Mr. Poole's patents for the Kingdom. Among the stipulations was one founded on the statement as to time ($7\frac{1}{2}$ hours) required to grind a $12'' \times 72''$ roll, which was made a condition of performance obligatory on Mr. Poole, under penalty of forfeiture of agreement. This was easily accomplished, however, as the Wurtemburg chilled roll for the test, from the nature of the iron, proved softer than any American one, and was turned to greater accuracy than can be reached with more intractable material, and but $3\frac{1}{2}$ hours were needed to effect the desired grinding.

But a more satisfactory exhibition of the excellence of the new process was afforded when a roll previously finished in the same workshop, was *tested* in the new grinding machine. This roll had been an especial effort, having been finished for the Vienna Exhibition, ground and polished to the highest brilliancy, and had *come back* from the exhibition with an award. It was found so tapering and generally imperfect, as to require and occupy two days' grinding to bring it to cylindrical form.

In 1868, when this method of grinding rolls was first introduced, there is said to have existed in all the paper mills of the United States but two "*stacks*" of chilled rolls; or, at least, Mr. Poole avers that he only knows of that number. These stacks were five rolls high, and the rolls were short, 48-in. and 62-in. faces, respectively. Chilled rolls were, however, commonly in use at that time, as super-calenders in writing paper mills—say from 24 to 30-in. face. No maker of paper machinery had ventured to make chilled rolls, for machine calenders of 72 to 84-in. face, which has been

demanded to meet the requirements of width, of the common Foudeinier machines. The stack shown at the exhibition of the Franklin Institute, was 11 rolls high, with 84-in. face, and is not an uncommon stack at this time. The great superiority of calendered paper, and of paper calendered by perfect rolls; in freedom from buckles; mottled, dead and bright places; and in parallelism of the sheet, has led to a rapid increase of calenders, both in this country and abroad. And an actual improvement in the manufacture of paper has been effected.

The several results can be summed up. The accomplishment of mechanical accuracy on philosophical and theoretical bases; the construction of machinery by economical and thoroughly practical process; and the consequent advancement of one of the greatest industries of civilization, *the manufacture of* PAPER. B.

AIR BAGS FOR RAISING VESSELS.*

Air being seven hundred times lighter than water, a bag made of a very light water-tight material, when filled with air, affords easy and powerful means wherewith to raise sunken bodies. Air bags are convenient for stowage and transport, because when not in use they occupy very little space, while at the same time when wanted they can be expanded into large dimensions. The greater the weight of body to be lifted by means of air bags, the larger, of course, must be their displacement, and as the bags are generally manufactured of certain fixed dimensions, the weight of the submerged body must determine the number of air bags to be applied.

The first to suggest the use of air bags for this purpose was Professor St. Claire, of the University of Edinburgh, who proposed them in the year 1785. But as the india-rubber industry was then but barely developed, air bags could not then have been manufactured of that material so as to be of practical use. So recently as in 1864, air bags were for the first time practically applied by Bauer for raising the steamer Louis, which sank in the Lake of Boden. But on that occasion, owing to the bags being pear-shaped, they could not sustain the pressure, and gave way. The idea of using the air bags in Russia originated with M. J. Alexandrovsky, and the system was adopted in 1865, at the time when the turret ironclad Smertch foun-

* From *Engineering*, London, October 29th, 1875.

dered in the Baltic sea. Mr. Alexandrovsky was supported by Admiral Popoff, of the Russian Imperial Navy, who assisted him greatly in bringing his invention into practice, carrying out experiments so as to render the air bag system what it now is, namely, a very valuable means of raising ships, etc., and which has already rendered good service to the government and commerce of Russia on several óccasions.

The air bags adopted in the Russian navy when inflated are of cylindrical form, measuring 12 ft. in diameter, and 20 ft. in length. The useful part of their displacement or their lifting power in practice averages 60 tons. Air bags measuring 15 ft. in diameter and 20 ft. long, will lift about 100 tons, and cost, acording to the number required, from 375*l.* to 350*l.* each in St. Petersburg. The skin of the bags, of the sizes mentioned, is composed of three layers of the thickest canvas, saturated with india-rubber. Between each of the canvas layers is a sheet of india-rubber. The two inner layers of canvas are made up of strips sewn together along their edges, and laid in the direction of the length of the bag, whilst the third or external layer is made of canvas strips surrounding the bag circumferentially. The strips of this last layer thus cross those of the layers underneath it. This arrangement of the skin layers secures in the bags the required amount of resistance and durability. The external surface of the bag is fitted with special straps through which it is surrounded with a close, strong rope net, which increases the strength of the skin, and a layer of matting is interposed between the skin and the rope net.

In order to distribute over the whole surface of the bag, the strain to which it is subjected when lifting heavy bodies, the bag is enveloped in a series of longitudinal and transverse, or circular hempen cables. To the lower ones iron eyes are fastened, which afford means to connect the chains securing the bag to the object to be raised. When necessary, an oak beam 12 ft. long and 14 in. or 16 in. square is attached to the cables which surround the bag transversely; and to this beam the connecting chains are made fast. Each of the air bags is fitted with a valve, which is screwed in at the top and in the centre, together with an india-rubber hose, by means or which air is forced into the bag. At the ends of the bag, also in its upper part, are two smaller valves with tubes intended for letting the air out, and for holding the pressure gauge, which is applied for the purpose of ascertaining the amount of pressure inside.

In the interior of the bag, along its bottom, two short lengths of hose are sewn in so that they cannot move laterally. One end of each of these pipes which is open, terminates close to the end of the bag and in the interior of it, whilst the other end passes out at the opposite end of the bag at the bottom, and is fitted with a safety valve, which opens when the bag is fully inflated with air, and the pressure begins to exceed the surrounding water pressure. By means of these two safety pipes and valve the bag is secured from bursting, and the pressure of the air within it distributes itself evenly in both ends of the bag. The bottom part is fitted with a man-hole sufficiently large to admit the entrance of a man, for inspecting the interior of the bag, and for repairs.

In order to lift the sunken vessel, it is necessary first to send down divers to examine her condition, and to find the spot where it would be most convenient to pass chains or cables underneath her keel. For this last purpose the divers at first pass a thin rope underneath the bottom of the vessel, which is followed by a rope of greater thickness, attached to the first, and terminating at the other end by a chain or the cable. It sometimes happens that the power of the divers below, and that of the windlasses above, though sufficient to draw a thin rope under the vessel, are insufficient to haul a thick cable. In such cases an air bag is attached to the end of the thin rope, and this bag being inflated acquires an ascending power sufficient to carry with it a cable of any required thickness. This method was successfully adopted, when a vessel sunk in a depth of 15 fathoms was being raised, and when the power of 200 men with windlasses proved to be insufficient to draw the chain underneath the vessel.

When several chains have been drawn underneath the bottom of the ship, the air bags are attached to the ends of each of them, as near to the bottom of the ship as possible. The bags being inflated by means of air pumps cause the ship to rise. Before pumping air into the bags, care is taken to connect together all the chains which surround the hull of the vessel in a transverse direction, so as to form a longitudinal continuous belt, which uniting all the chains into one system, prevents the end pairs of air bags sliding off from beneath the extremities of the vessel. As the ship rises, the surrounding water pressure decreases, and the excess of air passes out from the bags through the safety valves, with which each air bag is provided.

This method of raising vessels and other sunken bodies by means of air bags is of very great importance, especially when the work has to be performed in the open sea, because, in rough weather the bags without any air in them can be left under water with buoys to mark their position, until the weather becomes more favorable and the sea calm.

When lifting vessels from great depths, the work must not be accomplished by one process; that is, the whole number of air bags required to complete the work should not be applied to the ship at one time. This precaution is necessary, because, when the vessel, tied up with chains, and provided with the full number of air bags, ascends rapidly from a great depth, and gets to the surface of the water, it is raised, by means of its acquired momentum, higher than is consistent with equilibrium at the surface. Eventually, after attaining an unbalanced position, the whole is submerged again. This arises from the circumstance that from the moment the ship leaves the bottom of the sea, and during her ascent, the surrounding water pressure is gradually decreasing, and the air from the bags is passing out. Therefore, at the time when the ship reached the surface of the water, the bags would not possess the amount of lifting power necessary to keep her on the surface. Accordingly, the ship would return to the bottom. To prevent this, one, two, three, and in some cases four bags (according to the size of the vessel), out of the whole number required are fastened to the chains which surround the vessel, not close to her, but at a depth of some two or three fathoms below the surface of the water. By such distribution of lifting power, the vessel, having separated herself from the bottom of the sea, would ascend until the upper bags reached the surface of the water. The whole system is then towed to another place, where the water is shallower than where the wreck occurred. The air bags which reached the surface of the water at the first operation, are again submerged, and are tied to the chains several fathoms lower down. By repeating these operations several times, according to circumstances, the ship will be brought to the surface gradually, and by easy stages with the certainty of success.

These precautions are also necessary in those cases when, as it sometimes happens, the sunken ship, after having separated herself from the bottom of the sea, would be raised not horizontally, but with one end higher than the other. By having several air bags, out

of the whole number, attached at a depth of a few fathoms below the surface, it insures that the rise of the higher end of the vessl will be limited only to the height equal to those few fathoms, and the chains with the air bags surrounding the ship cannot slide from underneath her. This method of working affords a sure means of ascertaining whether there is any necessity to increase or decrease the lifting power at either extremity of the vessel.

In the year 1869, a merchant schooner foundered in the Baltic, and in order to save her heavy cargo, consisting of pig iron, air bags were made use of. This case proved how powerful the air bags were, because, when the upper part of the vessel was surrounded by the longitudinal belt of chains with the air bags attached to it, her deck, with the whole of the masts, spars and fittings, together with the upper strakes of her sides, were torn away by the power exerted by the bags, and were carried up to the surface, the breakage occurring just along the line where the bags were applied. After having thus opened the hold, her cargo, and afterwards the vessel herself, were lifted up easily and successfully. The next useful work performed with the air bags was the lifting, in 1870, of the gunboat Metch, which sank in the roads of Tranzund, in a depth of 21 feet.

Soon after this, in the same year, the steamer Ilmen, which had foundered near Viborg, was raised. The work was completed in the short space of ten days, thus proving the simplicity and ease with which the air bag system can be applied.

In the same year the ironclad Sevastopol was lifted for repairs by means of bags, so that access was obtained to the wooden planking separating the armor from the copper sheathing. The edges were caulked, and the planks replaced by new ones. By these means, in five days only, and with very little expense, the leakage from which the frigate suffered in 1869–70, and also the destruction of the lower armor plates, due to the action of copper sheathing, were successfully stopped. Had not the bags been employed, it would have been necessary to place the frigate in dock, and as the docks at Kronstadt, at that time, were not so deep as they are now, this work would have necessitated the removal of her armor—a heavy and very costly job—or the frigate could not have been commisioned until the new dock was completed. During the same year, also, air bags were used for raising the stern of the ironclad frigate Minin. With the help of two barges and four air bags, the frigate

was successfully conveyed over the Neva bar to Kronstadt. In 1870, the imperial yacht Standart being raised by means of eight air bags, was conveyed in a similar manner over the Neva bar. In this work, also, the use of air bags greatly reduced the expense, and saved much time. In the same year, the air bags were utilized for lifting up the stern of the ironclad Prince Pojarsky, when she was brought through the gate of Petrovsky Kronstadt Dock, where the ship had her armor plates put on, and whence she could not be taken out without taking these plates off again.

In 1872, in Biorke-Zund, a vessel sank in 90 feet of water. It was intended to lift her by means of barges, but this attempt failed, after much time and money had been spent. On the attempt being made with air bags, the work was successfully accomplished, notwithstanding that this vessel, owing to her cylindrical form, her comparatively small size, and her very heavy weight, proved to be very difficult to raise. The lifting of this vessel thus from the bottom of the sea, showed that the work could only have been successfully carried out by means of air bags.

The system afforded no less important aid in 1873, in the Black Sea, where the necessity occurred for changing the pitch of the propelling screws of the Popoffka Novgorod. The form of this ship did not allow her to be taken upon any slipways existing at that time. This work required but three bags, and by means of them the stern was lifted to a height of 5 feet.

Last year, a merchant steamer, the Dornkat, which foundered in 11 fathoms of water, near London Lights, in the Baltic, was lifted by means of eight air bags. Notwithstanding that at the beginning of the work the steamer was surrounded on all sides by the ground at the bottom of the sea, and was buried in it, and that the work was carried out in an open sea, the steamer was successfully raised.

In the autumn of last year, by means of the air bags, the stern of the Popoffka Novgorod was lifted twice for the purpose of lengthening the blades of the propelling screws, and to change their pitch. This year, air bags have been usefully applied on several occasions, and at present they render great services in the construction of the new bridge across the Neva, in St. Petersburg. In this case, they are used to keep in a vertical position the iron caissons during their erection. It will thus be seen that the air bag system is in every respect one which may be of great value to the royal and mercantile navy.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 262.]

With the vessel at the speed of 7 geographical miles per hour, and screw H revolving freely, the aggregate resistance of vessel and screw was 756 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 125 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{125 \times 100}{621} =\right)$ 19·81 per centum; and decreased its speed ($\sqrt{631} : \sqrt{756} :: 7 : 7·6620$ and $7·6620 - 7· =$) 0·6620 geographical mile per hour, or $\left(\frac{0·6620 \times 100}{7·6620} =\right)$ 8·64 per centum.

From the foregoing it appears that the resistance due to screw H when revolving freely, is 25·04 per centum of the resistance of the vessel, *per se*, less than when it is held stationary with one blade vertical *below* the shaft, immediately behind the vessel's stern-post; 37·40 per centum less than when it is held stationary with one blade verticle *above* the shaft, immediately behind the stern-post; and 32·65 per centum less than when it is held stationary with one blade horizontal, square across the vessel, on one side of the stern-post, while the remaining two blades are on the opposite side at angles of 30 degrees from the perpendicular.

General conclusions.—From the results of the preceding experiments made to determine the relative resistances of the screws of steam-launch No. 4 when dragged through the water in various positions and under different conditions, the following general conclusions can be drawn:

First. All the screws experimented with continued to revolve until the vessel's speed fell below $3\frac{1}{2}$ geographical miles per hour.

Second. That with the exception of the extreme case in which a two-bladed screw is employed, composed of such small fraction of the pitch that its projected area on a plane at right angles to the axis is covered or masked by the stern-post of the vessel, the two bladed screws gave much less resistance when revolving freely than when held stationary with their blades in the vertical position immediately behind the stern-post of the vessel.

Third. That even in the extreme case above excepted, and which never occurs in practice, the resistance of the two-bladed screw when held stationary with its blades in the vertical position immediately behind the stern-post of the vessel, was only 2 per centum less than when revolving freely. And that this slightly less resistance was due to the fact that, because it was masked by the stern-post, owing to the extremely small fraction of the pitch of which it was composed, it made, when revolving freely, fewer revolutions per minute than it would have made if composed of a larger fraction of the pitch, and consequently had to be dragged bodily through the water at a higher speed.

Fourth. That the resistance of the two-bladed screws when their blades were held stationary in the vertical position immediately behind the vessel's stern-post, was much less, for all the fractions of pitch employed, than when they were held stationary in the horizontal position square across the vessel. And that this difference of the resistance in the two positions became less and less as the screws were composed of greater and greater fractions of the pitch, all other things being the same.

Fifth. That in the case of screws otherwise identical, except that the surface in the one was divided into two blades, while in the other it was divided into four blades equispaced around the axis, the two-bladed screw when held stationary with its blades in the vertical position immediately behind the vessel's stern-post, gave a much less resistance at equal speed of vessel than the four-bladed screw when held stationary with two of its blades in the vertical and the other two in the horizontal position.

Sixth. The two-bladed screw under the conditions of fifth, also gave a much less resistance than the four-bladed screw with its blades equispaced around the axis, and held stationary at the angle of 45 degrees with the perpendicular.

Seventh. The two-bladed screws, when held stationary with their blades in the horizontal position square across the vessel, gave resis-

tances, at equal speed of vessel, in the direct ratio of the fraction of pitch of which they were composed, all other things being the same.

Eighth. The two-bladed screws, when held stationary with their blades in the vertical position immediately behind the stern-post of the vessel, gave, at equal speed of vessel, resistances increasing with the fraction of pitch of which they where composed, other things being the same. The ratio of this increase in function of fraction of pitch, the experiments were not sufficiently numerous and varied to determine.

Ninth. The two-bladed screws, with the exception of the extreme case in which a two-bladed screw is employed composed of such small fraction of the pitch that its projected area on a plane at right angles to the axis is covered or masked by the stern-post of the vessel, gave, when freely revolving, resistances in the direct ratio of the fractions of the pitch of which they were composed, all other things being the same.

Tenth. That with the exception of the extreme case above defined, the two-bladed screws, *ceteris paribus*, composed of whatever fraction of the pitch they might be, make, when revolving freely, at any speed of the vessel greater than 3½ geographical miles per hour, the same number of revolutions per mile. As the product of this number of revolutions and the pitch in feet is always less by a constant quantity than the geographical mile in feet, the two-bladed screws, composed of whatever fraction of the pitch they might be, are, for equal speed of vessel, dragged bodily at equal speed through the water.

Eleventh. That in the extreme case above excepted, the two-bladed screw of such small fraction of the pitch that its blades are masked or covered by the stern-post of the vessel, makes, when revolving freely, the same number of revolutions per mile at all speeds of vessel above 3½ geographical miles per hour; but this number is less than when the fraction of the pitch is greater, and this screw is consequently dragged bodily through the water at a greater speed than in that case, and has a corresponding greater resistance in proportion to its fraction of pitch.

Twelfth. The four-bladed screw with its blades equispaced around the axis and held stationary at angles of 45 degrees with the perpendicular, gave 8·7 per centum more resistance than when it was held stationary with two of its blades in the vertical position and the re-

maining two in the horizontal position. The above proportion, however, is only true for the particular fraction of pitch of which this screw was composed. It will become less for greater fractions and more for smaller ones. It nevertheless shows that the resistance of a blade, even when at the angle of 45 degrees with the perpendicular is much less than when in the horizontal position. Had the resistance of the blades in both these cases been equal, the resistance of the screw, with its blades at the angle of 45 degrees with the perpendicular, would have been 440 pounds when the vessel had the speed of 7 geographical miles per hour, whereas the experimental resistance at that speed was only 337 pounds, or 76·6 per centum of the former. The difference strikingly illustrates the effect exercised upon the resistance of the blade by the proximity of the hull.

Thirteenth. The four-bladed screw with its blades equispaced around the axis, gave a much less resistance when revolving freely than when held stationary in any position. And when identical with the two-bladed screw in all respects except the number of blades into which the same surface was divided, it gave, when revolving freely exactly the same resistance as the two-bladed screw when revolving freely at the same speed of vessel.

Fourteenth. The above four-bladed screw makes, when revolving freely at any speed of vessel greater than $3\frac{1}{2}$ geographical miles per hour, the same number of revolutions per mile; and this number is exactly the same as that made under the same conditions by a two-bladed screw of the same diameter and pitch, with a fraction of pitch sufficiently great not to be masked by the vessel's stern-post; As the product of this number of revolutions and the pitch in feet is always less by a constant quantity than the geographical mile in feet, the four-bladed screw is dragged bodily through the water at a speed which is always the same per centum of the vessel's speed, let the latter be what it may.

Fifteenth. The Mangin screw composed of two identical two-bladed screws placed one immediately behind the other, so that, when viewed in projection on a plane at right angles to axis, it appears like a single two-bladed screw, gave, at equal speed of vessel, when of the same diameter, pitch, and *projected area* on a plane at right angles to the axis as the two-bladed screw, exactly the same resistance as the latter under all the conditions of being held stationary with the blades in the vertical position immediately behind the vessel's stern-

post, of being held stationary with the blades in the horizontal position square across the vessel, and of revolving freely. But the Mangin screw, composed as above, has double the fraction of pitch and double the surface of the two-bladed screw above described; consequently, while the propelling efficiency will be greater than that of the two-bladed screw in the ratio of the square root of 2 to the square root of 1, its resistance at equal speed of vessel when dragging with its blades held stationary in any position, or revolving freely, will be only one-half of that of the two-bladed screw.

Sixteenth. In the cases of a two-bladed screw, a four-bladed screw, and a Mangin screw, all three having the same diameter, pitch, and fraction of pitch, or, in other words, being identical except as to number and arrangement of blades, their propelling efficiencies in smooth water are equal, but their resistances when dragging at equal speeds of vessel are very different. When these screws are revolving freely the resistances of the two-bladed and four-bladed are equal, while the resistance of the Mangin screw is only one-half of that of either. When these screws are held stationary and dragged through the water, the resistances, at equal speed of vessel, of the two-bladed screw and of the Mangin screw with their blades in the vertical position immediately behind the vessel's stern-post, and of the four-bladed screw with two of its blades in the vertical and the other two in the horizontal position, these positions for the three screws being those in which they have the least resistance when held stationary, compare as 100 for the Mangin screw, 219 for the two-bladed screw, and 344 for the four-bladed screw. As regards to the latter, however, this proportion is true only for the particular fraction of pitch (0·3570) of which these screws were composed. With larger fractions of the pitch the resistance of the two-bladed and four-bladed screws would be relatively less, and with smaller fractions of the pitch it would be relatively more, but in a higher degree for the four-bladed than for the two-bladed screw.

All these screws give the same number of revolutions per mile when revolving freely so long as the projected area of the Mangin screw on a plane at right angles to the axis is sufficiently large not to be covered or masked by the vessel's stern-post, and this number is constant at all speeds of vessel above three and a half geographical miles per hour, at which revolution ceased.

Seventeenth. The Griffith screw, though of the same diameter as the others, had a pitch so different in kind and dimensions, and blades

so different in number and shape, that no comparison can be made with them. There can only be drawn the general conclusion, that screws with larger pitches when revolving freely, make fewer revolutions per mile and have the product of that number of revolutions and the pitch in feet a greater proportion of the mile in feet than screws of smaller pitches.

Eighteenth. The foregoing conclusions, though qualitatively exact for the kind of screws experimented with, let their absolute dimensions of diameter, pitch, and friction of pitch, be what they may, so long as these remain the same for all, and let them be applied to what form or dimensions of vessels they may, yet quantitatively will be modified by all the circumstances just enumerated, with the exception that whether the same kind and quantity of surface to be arranged in two blades, four blades equispaced around the axis, or four blades with two immediately behind the other two, as in the Mangin screw, the resistance when dragging and revolving freely will be as stated in sixteenth; and that they will all make the same number of revolutions per mile of the vessel's speed.

In the following Table No. 1, will be found the dimensions of the experimental screws, which, though given in the preceding report on their propelling efficiencies, are here re-inserted for conveniences of reference.

In the succeeding Table No. 2, will be found collected under appropriate headings, the numerical results of the experiments made with the screws dragging under various conditions.

Table No. 1, containing the principal dimensions of the screws employed in the foregoing experiments.

Designation of the screws.	Diameter, in feet.	Diameter of hub, in feet.	Pitch, in feet.	Number of blades.	Length of each blade in direction of axis, in feet.	Fraction used of the pitch.	Projected area of the blades on a plane at right angles to axis, in square feet.	Helicoidal area of the blades in square ft.
A..............	4·3333	0·50	5·136	2	0·9167	0·3570	5·1950	6·1321
B..............	4·3333	0·50	5·136	2	0·7187	0·2799	4·0730	4·8078
C..............	4·3333	0·50	5·136	2	0·4583	0·1785	2·0975	3·0661
D..............	4·3333	0·50	5·136	2	0·2604	0·1014	1·4755	1·7417
E..............	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
F*..............	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
H†..............	4·3333	1·25	7·000	3	‡0·9167	§ 0·2034	2·7495	4·2968

* Mangin or duplex screw. † Griffith screw, with expanding pitch from 6⅔ ft. to 7½ ft.
‡ Maximum. § Calculated for the mean pitch of 7 feet.

Table No. 2, containing the results of the trials made to ascertain the dynamometrical resistances of the experimental screws of the United States steam-launch No. 4, when it was towed by the steamer Monterey, with the screws dragging under the different conditions of revolving freely by the pressure of the water on the forward side of their blades, and of being held stationary in different positions.

Kind of screw, and conditions of its trials.	Designation of the screws.	Speed.				Resistances.				Loss of vessel's speed due to the drag of the screw.		
		Speed of the vessel, in geographical miles per hour.	Number of revolutions made by the screw per geographical mile.	Speed of the screw, in geographical miles per hour, calculated from the pitch and the revolutions.	Difference, in per centum of the speed of the vessel, between the speed of the vessel and the speed of the screw.	Resistance of the vessel alone—*i.e.*, without any screw—in pounds per dynamometer.	Resistance of the screw alone, in pounds per dynamometer.	Aggregate resistance of vessel and screw in pounds per dynamometer.	Resistance of the screw, in per centum of the resistance of the vessel alone.	Speed, in geographical miles per hour, that the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.	Loss of speed in geographical miles per hour, due to the resistance of the screw.	Loss of speed due to the resistance of the screw, in per centum of the speed the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.
2-bladed screw;												
Revolving freely by the pressure of the water	A	7	921	5·441	22 28	631	134	765	21·24	7·7075	0·7075	9·18
Held stationary, with the blades vertical behind the stern-post	A	7	....	......	....	631	350	981	55·47	8·7281	1·7281	19·80
Held stationary, with the blades horizontal, square across the vessel.	A	7	....	......	....	631	440	1,071	69·73	9·1196	2·1196	23·24
2-bladed screw:												
Revolving freely by the pressure of the water	B	7	921	5·441	22·28	631	105	736	16·64	7·5600	0·5600	7·41
Held stationary, with the blades vertical behind the stern-post	B	7	....	......	....	631	197	828	31·22	8·0186	1·0186	12·73
Held stationary, with the blades horizontal, square across the vessel.	B	7	....	......	....	631	345	976	54·68	8·7058	1·7058	19·59
2-bladed screw:												
Revolving freely by the pressure of the water	C	7	921	5·441	22·28	631	67	698	10·62	7·3623	0·3623	4·92
Held stationary, with the blades vertical behind the stern-post	C	7	....	......	....	631	90	721	14·26	7·4826	0·4826	6·45
Held stationary, with the blades horizontal, square across the vessel.	C	7	....	......	....	631	220	851	34·86	8·1292	1·1292	13·89
2-bladed screw:												
Revolving freely by the pressure of the water	D	7	757	4·472	36·12	631	54	685	8·56	7·2934	0·2934	4·02
Held stationary, with the blades vertical behind the stern-post	D	7	....	......	....	631	26	657	4·12	7·1428	0·1428	2·00
Held stationary, with the blades horizontal, square across the vessel.	D	7	....	......	....	631	125	756	19·81	7·6620	0·6620	8·64
4-bladed screw, blades equidistant:												
Revolving freely by the pressure of the water	E	7	921	5·441	22·28	631	134	765	21·24	7·7075	0·7075	9·18
Held stationary, with one pair of blades vertical and other horizontal	E	7	....	......	....	631	310	941	49·13	8·5483	1·5483	18·11
Held stationary, with the blades at the angle of 45 degrees with the vertical	E	7	....	......	....	631	337	968	53·41	8·6696	1·6696	19·26

Table No. 2, containing the results of the trials made, etc.—Continued.

Kind of screw, and conditions of its trials.	Designation of the screws.	Speed.				Resistances.				Loss of vessel's speed due to the drag of the screw.		
		Speed of the vessel, in geographical miles per hour.	Number of revolutions made by the screw per geographical mile.	Speed of the screw, in geographical miles per hour, calculated from the pitch and the revolutions.	Difference, in per centum of the speed of the vessel, between the speed of the vessel and the speed of the screw.	Resistance of the vessel alone—*i.e.*, without any screw—in pounds per dynamometer.	Resistance of the screw alone, in pounds per dynamometer.	Aggregate resistance of vessel and screw in pounds per dynamometer.	Resistance of the screw, in per centum of the resistance of the vessel alone.	Speed, in geographical miles per hour, that the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.	Loss of speed in geographical miles per hour, due to the resistance of the screw.	Loss of speed due to the resistance of the screw, in per centum of the speed the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.
4-bladed screw, Mangin's system:												
Revolving freely by the pressure of the water.....	F	7	921	5·441	22·28	631	67	698	10·62	7·3623	0·3623	4·92
Held stationary, with the blades vertical behind the stern-post......	F	7	....	......	....	631	90	721	14·26	7·4826	0·4826	6·45
Held stationary, with the blades horizontal, square across the vessel.	F	7	....	......	....	631	220	851	34·86	8·1292	1·1292	13·89
3-bladed screw, Griffith's system:												
Revolving freely by the pressure of the water......................	H	7	665	5·3541	23·51	631	125	756	19·81	7·6620	0·6620	8·64
Held stationary, with one blade placed vertically below the shaft, and the remaining two blades above the shaft at angles of 60 degrees from the vertical..	H	7	....	......	....	631	283	914	44·85	8·4247	1·4247	16·91
Held stationary, with one blade placed vertically above the shaft, and the remaining two blades below the shaft at angles of 60 degrees from the vertical..	H	7	....	......	....	631	361	992	57·21	8·7768	1·7768	20·24
Held stationary, with one blade placed horizontally on one side of the vessel's stern-post, and the remaining two blades on the other side at angles of 60 degrees from the vertical......................	H	7	....	......	....	631	331	962	52·46	8·6431	1·6431	19·01

PNEUMATIC TELEGRAPHS FOR LONG DISTANCES.*

Paper read at the Meeting of the Society of Civil Engineers of Paris, on the 4th of June, 1875.

By M. A. Crespin.

[Continued from Vol. lxx, page 285.]

In the present state of the question it seems evident that, even taking into account a postal service already well developed, the diameter of a pneumatic tube should never exceed one-tenth of a meter; under these conditions the limit of remunerative cost has been reached, beyond this limit the cost becomes greater than that of a railway. If such a tube is worked by engines of sufficient power, it can transmit as many as 100 boxes per hour, representing nearly 100 kilograms weight of messages, which, divided into letters of 20 grams each, would equal 5000 of such letters per hour.

It is evident that a traffic of this kind would be far in excess of the amount of work possible at the present time.

We have just seen by what has been previously stated on the subjects of pressure and diameter, that these two elements in the establishment and working of a pneumatic tube, cannot, practically, be extended beyond certain limits; we now proceed to examine the influence of the length itself. We again revert to the fact that all the advantages of a pneumatic telegraph consist in its compensating, by its capacity, for its relative slowness as compared with electricity. It is necessary therefore, if we wish to go far, to go at a high speed; we have just seen within what limits we can avail ourselves of increased pressure and diameter, and the result of our examination is, that a solution of the problem must be sought in some other direction.

The first investigations of the subject date from 1857; they were made by Mr. Latimer Clark, who brought forward the question of the necessity for a mechanical arrangement to allow of the working of lines of comparatively great length. A kind of opening was arranged which was closed by means of special mechanism at the moment a train passed, when a train was being impelled by compressed air, and was opened upon the passage of a train in the opposite direction, drawn inwards by the vacuum.

The advantages of a plan of this kind were indisputable, and we find in the journal *Engineering* of the year 1869 the description of an apparatus proposed by Mr. Sabine, which affords a satisfactory solution of the problem.

* Extracted from the *Telegraphic Journal*, London.

Mr. Sabine has taken the case of a line similar to one of the principal line radiating from the Post Office in London, and constituting a line of communication with a point more or less distant by means of trains alternately driven forward by pressure of air, and afterwards drawn back again by a vacuum applied at the end of the tube terminating in the central station.

His arrangement consists of a valve acted upon through a hinged rod by a sort of diaphragm of leather or india-rubber, the latter being influenced through a special tube by the vacuum or pressure at the central station. This diaphragm opens the valve, and when sending by pressure the air, by escaping through the opening, allows the train to traverse the first section as if the line consisted merely of the length between the starting point and the valve. The moment the train passes the opening, it detaches the valve from the rod which connects it with the diaphragm, by the action of a spring; the valve then closes, and the train passes through the second section with the speed proper to a line having the length of the two first sections, and so on.

If the central station draws a train from the extreme end, the apparatus acts in the following manner: by means of the vacuum actuating the diaphragms through the special tube, all the valves are closed, the line can then be exhausted of air in front of the train which, as it passes the valves, acts upon the bolts, and thus disconnects them, so as to allow the air to enter behind the train at the end of each section; the same advantage is thus obtained as when sending by pressure.

The table given below shows the advantage gained by employing this apparatus; a line of ten sections is taken for example.

No. of Section.	Time of transit in each section.		Total time of transit. With Valve.	Without Valve.		Percentage of gain.
1	1		1	1		
2	$\sqrt{2}$	1·41	2·41	$2\sqrt{2}$	2·82	17
3	$\sqrt{3}$	1·73	4·14	$3\sqrt{3}$	5·19	25·4
4	$\sqrt{4}$	2·00	6·14	$4\sqrt{4}$	8·00	30·3
5	$\sqrt{5}$	2·24	8·38	$5\sqrt{5}$	11·20	33·7
6	$\sqrt{6}$	2·45	10·83	$6\sqrt{6}$	14·70	35·7
7	$\sqrt{7}$	2·65	13·48	$7\sqrt{7}$	18·55	37·6
8	$\sqrt{8}$	2·83	16·31	$8\sqrt{8}$	22·64	38·8
9	$\sqrt{9}$	3·00	19·31	$9\sqrt{9}$	27·00	39·8
10	$\sqrt{10}$	3·16	22·47	$10\sqrt{10}$	31·60	40·6

From this table it is seen that the percentage of gain goes on increasing as the line becomes longer; the gain which is 17 per cent. for a line of two sections, with only one apparatus in the middle, increases to 40 per cent. upon a line of ten sections provided with nine of the apparatus distributed throughout its length.

The remedy is, however, far from being a radical one, for, if it allows pneumatic lines to be extended in length, it limits this extension, and the same table which shows the advantage of the apparatus, shows also very clearly the limit of the same extension; for we see that even with the proposed improvement it takes 3·16 times the time to traverse the tenth section that is necessary to pass through the first, and that averaging the gain over the whole length, the mean time occupied is represented by 22·47 instead of 10, which would be the figure were all the sections traversed at the same speed as the first. The mean speed after the tenth section has been passed in less than one half; the time occupied is nearly three times what it ought to be.

The solution of the problem of a line of unlimited length with a constant speed required a more complete apparatus, and it is this apparatus to which I have given the name of *relay*, that I am about to describe. Its object is to perform in the most complete and exact manner the operations which would be carried out by an attendant who, under conditions about to be described, would have to act in the following manner.

The pneumatic line of extended length has been, as in the case of lines established within the limits of cities, divided into sections of about one thousand meters in length; each of these sections is furnished at its commencement with reservoirs in which is stored up the compressed air, having the pressure and volume necessary for performing the service of the section. The case is exactly the same as that of an intermediate station in a city, provided with means for compressing air; the two lines up and down are arranged in a straight line, end to end, in such a way that a train received on the up line can pass without impediment into the down line; the attendant, whose presence we assume, would await the arrival by the up line of a train which was being sent to him, allowing to the air to escape freely at the end of the section. At the moment when the train passes from the up line into the down line he closes the former behind the train, and opening a cock communicating with his own reservoir of compressed air, by this means drives the train forward along the next section;

he keeps the cock open whilst the train is passing to the next station, and closes it when informed of its arrival at the latter point by the attendant there in waiting.

Such are the various operations which must be performed automatically by the relay; the first apparatus used and giving certain results was tried in the month of May, 1873. The trials were made in Paris, upon the direct line from the Central Station to the Bourse; and in London, in the engine-room at Telegraph-street.

At Paris the apparatus was placed under a cast iron plate, and was connected by special pipes with the reservoirs of compressed air in the station at the Théâtre Francais.

This apparatus fulfilled exactly all the operations above described as having to be performed by the attendant supposed to be placed at the intermediate station. The escape of the air took place in front of the relay, where a portion of the tube was perforated on all sides so as to give a passage to the air equal to twice the section of the tube. The closing of the line behind the train, and the opening of communication with the compressed air reservoirs were governed by a kind of trigger, and acted upon by the train directly it had passed through the relay. The duration of the blowing was determined by a piston rising in a cylinder through the effect of the internal pressure; the rising of this piston was regulated by the counter-pressure in such a way that the blowing continued somewhat longer than the time necessary. The moment a train arrived at its destination or entered a further section the pressure being destroyed in the line the weight of the regulating piston caused it to fall and remain in position to await the arrival of another train.

The success of this apparatus was complete; it enabled a certain number of trains to be passed to and fro between the Central Station and the Bourse with a saving of more than half the time. The return journey was equally rapid, for the trains were sent by pressure as far as the relay, the escape of air taking place through the perforated part of the tube; the rest of the journey was accomplished by means of vacuum from the Central Station.

The objection made to this apparatus is its delicacy; it contains within it a piece easily broken, this piece is the valve employed to close the line; if a foreign body hinders, even partially, its action the relay becomes nothing but an obstacle preventing, in the most absolute manner, the passage of the trains.

To remedy this objection it becomes necessary to do away with this valve which, after the description which has just been given, would seem to be the essential feature of the apparatus, since it is that which separates the outlet from the inlet. It could only be removed by suppressing the outlet, and to enable the latter to be dispensed with, the counter-pressure must be taken away.

It is this chain of observation which has guided me to the formation of the plan which I now proceed to set forth, and which completely solves the problem. The line is double acting; by means of special apparatus which are also relays, it is kept constantly exhausted of air and there is consequently no longer any counter-pressure nor are there any valves in the pressure relays.

By the side of the line, which we may assume to be of unlimited length are laid two secondary tubes connecting the reservoirs of vacuum and compressed air for the supply of the relays, which are placed in convenient positions along the course of the line. These relays are of two kinds; those destined to exhaust the line of air are placed five kilometers apart where it is intended that trains shall be sent along the line at intervals of a quarter of an hour. The reason for their being placed at this distance apart is, that a rather less space of time is needed for exhausting five kilometers, and there is, therefore, no advantage gained by placing them nearer together. They are of a very simple form, a piston rising in a cylinder carries with it a valve closing the line, and a slide opens the communication with the vacuum reservoirs; the piston is raised in the cylinder on the passage of a train, by the counter-pressure which follows the moving power, it closes the line behind it, and at once starts the exhaustion of the section of line which has just been traversed by the train. The valve of this relay has none of the objections attaching to that of the former relay, seeing that it opens of itself after the exhaustion of the section appertaining to the vacuum relay has been completed, an operation which is generally accomplished in half the time prescribed for the interval between the passage of two trains. Moreover, as these relays are placed every five kilometers, and at least one half of them are in places provided for compressing and exhausting the air, they are under the eyes of the attendants. The pressure relays placed one kilometer apart become simple blowers, opening on the passage of a train, and blowing all the time the train is traversing the section;

they merely consist of a piston pushing a counter-weight acting upon a slide, which is the pressure slide, and the regulating piston which stops the admission of air after the blowing has lasted the proper time; the compressed air enters the line by a kind of grating which uncovers openings having twice the sections of the line, and the blowing is governed by the train itself which, acting upon a trigger, lets fall a counter-weight placed upon the piston working the slide. The blowing is instantaneous: it is stopped by the action of the regulating piston which closes the communication leading to the line, and shuts up the compressed air in a small chamber between the point where the communication is thus closed and the slide. The effect of this compressed air at the moment when the pressure is lost in the line, that is to say, at the moment when the train has passed through the section, is to raise the piston acting upon the slide, and to restore everything into position for the arrival of another train. This apparatus, which is the main feature of the new system, is extremely simple, and does not require personal supervision in its working. It is accompanied by a reservoir of compressed air of sufficient capacity for the section.

I need not here discuss in detail the means by which the compressed air and vacuum are to be brought to the reservoirs serving the relays. Any of the methods usually employed for this class of work can be made use of, but the most economical process would, of course, be selected. In a populous country the engine stations might be numerous, and the power employed small. In thinly inhabited countries they might be 20 or 25 kilometers apart, and the power would then have to be greater.

I now proceed to the consideration of the speed with which the boxes will travel in a pneumatic line of unlimited length, in which, by the methods described above, the vacuum will be kept at 0·5 meters of mercury, and the pressure, admitted by the relays at intervals of 1000 meters, equal to 0·76 meters of mercury; the tube to be one-tenth of a meter in diameter.

My point of comparison will be the speed in the tubes of the Paris system, where a pressure of 0·4 meters of mercury gives a speed of 20 meters per second, in a line 1000 meters long, and 0·066 meters in diameter.

The increase of diameter will increase the speed in the proportion

$$\sqrt{\frac{100}{65}} \text{ or } \frac{10}{8}$$

say 25 meters per second.

The fact that the line if kept exhausted of air will reduce the friction in each length of 1000 meters to an average equal to that of 600 meters at most, for at the beginning of each section, that is to say, at the moment when the train passes the pressure relay, there is no column of air traveling with it; at the termination of the section only, will the column of air which drives the train have a length of 1000 meters. If the vacuum were perfect, the average friction length of the column of air would be but 500 meters. The diminution in the frictional length of the column of air gives an increase of speed in the proportion

$$\sqrt{\frac{1000}{600}} = \frac{33}{24}$$

The speed, raised to 25 by the increase of diameter, now becomes

$$25 \times \frac{33}{24} = 36 \text{ meters.}$$

We have then the increase of the differences of pressures, which is also in the ratio of the roots

$$\sqrt{\frac{26 + 50}{40}} = \frac{115}{65}$$

The application of this last ratio indicates a speed of nearly 70 meters per second.

This is an enormous speed, and would in all probability be attended with some inconveniences, but it is evident that we should work with the highest speed possible.

Now, observations made with trains running under similar circumstances at speeds of 40 to 50 meters, have shown that these practical speeds are quite admissible in regular working. It is only necessary to employ a very strong material, arranged in such a way that it alone shall wear without wearing the line; this end is attained by fitting the rubbing parts of the boxes with a softer metal than that composing the line.

The two ends of the line are provided with apparatus suitable for sending and receiving, in which precautions are taken to secure a

considerable slackening in the speed of the train when approaching its destination.

This effect is obtained by causing the air in front of the train to be compressed in the last hundred meters leading to the receiving apparatus; this compressed air is allowed to escape slowly in such a way that the train rises slowly into the apparatus.

Pneumatic lines with relays would certainly be a valuable means of communication for correspondence between distant places. The facility with which trains can be multiplied upon these lines without considerable expense, the speed which they can attain, and even the small net cost of the system, if too large a diameter be not employed, would make it one of the greatest utility to the Postal service.

The speed of transmission is three times that of the fastest railway train, if the stoppage of the latter are taken into account, and the establishment of the system upon lines where several days are required for exchange of letters, would evidently be of immense service.

A line of this kind has been proposed for establishing rapid communication between the Assembly at Versailles and the Ministerial offices in Paris; its execution would be a first step in this path, which is little known and which has been but little explored.

Useful Effect of Gunpowder in a Cannon.—M. De Saint Robert, in an article from his pen in the *Revue Scientifique*, gives the following calculation of the efficiency of a rifle cannon, the diameter of the bore of which is 7·5 centimeters = 3 in.—the shell of which weighs about 3·7 kilograms = 8·3 lb.—and the firing charge of which is 0·55 kilogram = 1¼ lb. It may thus be estimated:—Experiment has shown that the velocity of the shell when it leaves the mouth of the cannon is about 400 meters = 1300 ft.—per second. The height from which the projectile would have to fall to acquire this velocity is 8158 meters = 26,800 ft. Consequently the work actually done by the powder is equal to 30·185 kilogrammeters = 219,000 foot-pounds. On the other hand, Bunsen and Schischkoff have found by direct experiment that the heat evolved by the combustion of a kilogram of gunpowder is equal to 619·5 calories. Hence the heat evolved by the above charge of 0·55 kilogram is equal to 340·7 calories. The mechanical work corresponding to this amount of heat is 144,798 kilogrammeters = 1,050,000 foot-pounds. Comparing this, which is the possible mechanical work, with the actual work done on the projectile as given above, the ratio is 0·208 for the effectiveness of the cannon; that is to say, about 21 per cent.

ON THE NECESSITY OF A MECHANICAL LABORATORY; ITS PROVINCE AND ITS METHODS.*

By Professor R. H. Thurston.

1. *Introductory.*—There are few men of any considerable practical experience in engineering who have not felt the great need of some well established and reliable authority to which they could apply for special information, either purely scientific or more strictly professional, bearing upon unfamiliar details of their work.

Probably every man who has grown up in daily contact with any branch of mechanical industry has seen hundreds and often thousands of dollars expended in the effort to obtain such information, and has seen the result accomplished, and the information, valuable as it was to many besides those who acquired it, remaining unpublished. The world at large has been left as ignorant as before.

Repetition of the work by others has followed, and a similar expenditure of money has produced the same limited result. Where one thousand dollars properly expended in securing the desired knowledge would suffice, were the results properly communicated to the profession, ten thousand or twenty thousand dollars may be expended by as many independent experimenters, each ignorant of the other's work; and, after all, the hundreds of others who might have been benefited received no assistance.

In many other cases experiments have been carried on, and large sums of money expended upon them, without the slightest really new and valuable information being gained, either because the experimenters were unaccustomed to such work, and had but a vague knowledge of the real object to be attained, and still less knowledge of the proper method of obtaining it, or because of their unfamiliarity with the best methods of investigation, or in consequence of their ignorance of what had been already discovered and published by others.

*A paper read before the American Railway Master Mechanics' Association.

It often happens, also, that a long course of experiments or a most tedious, elaborate, and expensive investigation is comparatively barren of results, in consequence of some apparently slight neglect which would not have occurred had the investigator been accustomed to such accurate work as is required.

Again, it has very frequently happened that engineers have remained for many years in ignorance of the real nature of some familiar phenomenon, or of some important principle, simply because, in order to enable the subject to be intelligently studied in all its relations, its complete investigation required a comparison of experiments made in the chemical or the physical laboratory, with the work of the mechanic. The mechanical properties of materials; the effect of temperature upon the metals; the incrustation and corrosion of steam boilers; the value of lubricants; the heating power of fuels; all these, and many other subjects, require for their full investigation the highest talent of the chemist, and of the physicist, as well as of the engineer.

The serious necessity of the establishment of some great institution which should be solely devoted to the work of investigation of such scientific and professional problems as are daily being presented to the engineer and the mechanic, in the progress of regular work, was forcibly impressed upon the mind of the writer when—then but a boy amusing himself in the workshop and the drawing-room—he found himself unable to obtain accurate information upon even the most important subjects involved in the design of the steam engine, or in the proportions of its details, and especially information relative to those circumstances which determine the quality of the materials used. The size of a piston rod, the thickness of a cylinder head, the proportions of a crank pin, were usually determined, in nearly every shop, not by rules based upon careful investigation of the strength of the material, but by "rule of thumb." The economical value of high steam and of expansion, the influences of piston speed, the laws governing the deposition of the salts held in solution in spring water or in salt water; the effect of surface condensation on the efficiency of the engine and upon the durability of the boiler, are all subjects in regard to which engineers held widely discordant opinions. The real effect of heat and cold upon materials was uncertain, and the laws governing the resistance of metals to blows, it was asserted, were involved in mystery.

When, in later years, he was intrusted with sometimes important work, more light was the reward of painstaking investigation, but it came slowly and was most unsatisfactory from its meagerness. Experience in the management as well as design of engines and machinery at sea and on shore, revealed still more fully a great want of information in the most important branches of engineering work. We are getting on more rapidly to-day, but still too slowly.

Abroad, some valuable work has been done—far more than in the United States, although something has been done here. Our knowledge of the strength of materials rest, upon the researches of General Morin, of Tredgold, Hodgkinson, Fairbairn, and Barlow, of Chevandier, and Werthiem, and of Vicat. Kirkaldy, Styffe, and Bauschinger have made the latest and most valuable contributions from foreign sources. In this country, a committee of the Franklin Institute, and Captain Rodman and Major Wade of the Army, Chief Engineer W. H. Shock of the Naval Engineer Corps, and a few others, have done good work, while Commander Beardslee, United States Navy, has recently added important facts to those previously acquired. The experiments of Clark in England, of Bauschinger on the Continent, and of Forney in the United States, have thrown some light on the methods of distribution of steam in locomotives. The labors of Tresca, of Morin, and of Coulomb on the laws and facts of friction are the basis of our knowledge of that subject. Our own Professor Johnson, gave us an immense amount of information relative to the values and characteristics of American coals; and Baron Von Weber has given us important knowledge relating to the permanent way, from experiments on European railroads. Thus we find that some valuable work has been done in every line of research which has become the standard that guides us in practical applications.

In nearly every case we shall find, on investigation, that the standard which conservatism insists upon our accepting as a guide in our work has been some time in existence, and that it is based upon experiments with materials which were quite different from those now in our markets, and that it was made when methods now perhaps obsolete were considered satisfactory. In every field of labor we therefore meet with more or less unexplored paths, and we find ourselves daily at a loss to determine the best method of doing our work. The best work which has yet been done in the most important branches of research has usually been of such a broad character, and has demanded

the expenditure of so much time and money that it has of necessity been done by governments or by wealthy corporate bodies.

Abroad we have in the French "*Conservatoire des Arts et Metiers;*" and in the laboratories of great technical schools of Europe, may be found men competent to do good work, and who are assisted by the pecuniary aid of their governments. It thus happens that we owe very much to them. In this country the same system which gives us political freedom operates against the successful prosecution of such work under the patronage of government. In matters of pure science, as in the work of the Smithsonian Institute, in that of the coast survey, and in the occasional astronomical or geological expeditions which are carried out at public cost, the difficulties are not so serious. But investigations which have a directly practical bearing are liable to fall into the hands of those who are not thoroughly well prepared for the work.

It seems very certain that a really successful and permanently useful institution, devoted to investigation, must be partially, if not entirely, sustained by private individuals legally responsible, and well known as qualified for their work.

2. *Methods and investigations.*—The method of operation in the prosecution of any investigation may be detailed in a few words:—

a. The investigator must first know definitely what phenomenon it is proposed to investigate. A vague desire to know more of any given subject is by no means sufficient to justify entering upon a work which may be found to be indefinite in its extent and infinite in its ramifications. As a rule, the more completely the work may be narrowed down the better. It must necessarily be ultimately resolved into one or more questions which may be stated with precision before any probably intelligent and remunerative work can be commenced.

For example: To determine the effect of cold upon rails and machinery, which has been so often attempted and which still remains to a considerable extent, an unsolved problem, we may find ourselves compelled to resolve this question into several, as, for instance:—

(1.) What is the effect of change of temperature upon the strength of pure iron?

(2.) What upon iron containing carbon chemically combined, *i. e.* steel?

(3.) What upon iron containing carbon mechanically combined?

(4.) What upon iron containing sulphur chemically combined?

(5.) What upon iron containing phosphorus?
(6.) What upon iron containing silicon?
(7.) What upon iron containing cinder?
(8.) What upon steel containing sulphur?
(9.) What upon steel containing phosphorus?
(10.) What upon steel containing silicon?
(11.) What upon metal containing mixtures of these substances in the various proportions frequently met with?
(12.) What is the effect of change of temperature upon the ductility of all these metals?

And when we speak of the effect of low temperature we must not forget that it may have, and in fact does have, an effect in at least two ways: It will affect the resisting power of a material, especially under shock, not only by the change of molecular force which is due to the change of the relative distances of the molecules, but also by the simple fact of change of density itself.

b. Having determined all of these several simple effects, it remains to collect them and to so group the results that the great law underlying their action may be detected; and then the often exceedingly difficult task arises of expressing that law mathematically, or in some other way, which may make the work practically useful. It is evident that this problem can only be solved by a combination of the intelligent efforts of the chemist and the physicist as well as of the mechanic.

Thus our simplest questions may, upon examination, be found to comprehend complex and often difficult problems, and may require for their solution the highest talent of not merely one man, but of a number of specialists, all of whose labors may be required to secure a satisfactory solution.

c. After deciding precisely what is to be learned, the next step is usually to ascertain how much has already been done of the work thus determined and limited. This usually requires a careful examination of the records of previous professional work extending far back into earlier times; and it frequently happens that a vast amount of valuable information may be gleaned, and the work immensely shortened, by studying the results already made public by native and foreign experimenters. Much of the finest and most practically valuable work of their kinds which has been yet accomplished will be found described in French and German engineering works and period-

icals. The long standard works of Morin and of others already mentioned are illustrations.

d. Next after the labor of examining and collating earlier researches, comes the planning of the new investigation proposed. This is as necessary a preliminary as is the designing of an engine before work is commenced upon it in the shop. A thoroughly considered and well matured plan of operation will usually prevent any serious errors involving expenditure of money, or, what is equally important, the loss of valuable time.

The formation of a plan of operations requires a very definite knowledge of the character of the problem and an accurate understanding of the relative importance and probable bearing of the anticipated results, and a knowledge of the facilities available for the investigation. It presupposes a knowledge of the adaptation, range, accuracy, and reliability of the apparatus to be used; and not less important than all this is the knowledge of the extent to which assistance must be asked of, and how far aid may be expected from, special researches of a more purely scientific nature. Skill in experimentation thus guided will then produce the best results attainable with the means at hand.

e. The next requirement is a proper collation and registry of results, a work in which there is opportunity to make useful a considerable degree of ingenuity and talent.

f. To make correct deductions from the records, is the final task, and this is an exceedingly important matter. A lack of knowledge of the subject or of collateral facts may destroy the value of the whole work.

This work being properly done and the account of the research being properly written out, a contribution to knowledge will usually be found to have been secured which has a value to the public, and sometimes to individuals, far exceeding that of the time and the money expended in securing it. Men of science have often devoted the best years of a life-time to the investigation of a single train of phenomena, seemingly insignificant in comparison with the great facts surrounding them; yet neither they nor the world think this a wasteful expenditure of time. The value of acquired knowledge is never to be measured by the value of immediately apparent results or of evident applications; yet, in the course of the practice of the engineer and the mechanic, it rarely happens that such experimental-

work as he is compelled to take in hand does not bring an immediate and ample remuneration, while the ultimate benefit accruing is often immensely great in proportion to what is paid for it.

We usually find that we help ourselves by such work to a most satisfactory extent, and at the same time are enabled to give our neighbors of our light without sacrifice, and to experience the gratification of benefiting the profession and the public.

3. *Locating a mechanical Laboratory.*—The location of such an establishment as would be well adapted to general work of the kind here contemplated, and to the prosecution of special investigation of a directly or indirectly practical character should be carefully selected.

The necessity of frequently calling for advice and assistance of both practical and scientific men, and the desirability of securing accessibility will prevent its satisfactory operation if it is not located so as to be within reach of a large proportion of those most interested in its establishment and maintenance.

The necessity which will frequently arise of making accessory investigations of a scientific character, in various branches of natural science, will dictate its establishment, probably, in connection with some conveniently situated and well established technical institution of learning, provided with well stocked laboratories, conducted by men capable of appreciating the importance of the work and of properly pursuing such investigations and who will take an interest in the subject.

The institution should have a character which is readily defined. Its magnitude is not so easily determined. It may be of very limited extent, and may yet do a vast amount of good; or it may become a vast establishment, employing a large corps of able men, making use of extensive collections of valuable apparatus for machinery, and making profitable use of larger capital than the French "Conservatoire des Arts et Metiers," already alluded to, which has an annual income of nearly seven hundred thousand francs, five hundred thousand of which come from the state. In a large and growing country like ours, peopled by the most active and enterprising of every race, the future of such an institution, if properly managed, would be whatever its managers and those whom they aid might choose to make it.

Its stock of apparatus would be determined, in character and extent, by the nature of the work most imperatively needed. It

would probably comprise a set of machines for testing the strength and other no less important qualities of the materials of construction, dynamometric apparatus, instruments for testing lubricants, steam engine indicators, calorimeters, pyrometers and thermometers, and apparatus for determining the heating power of fuels. A mercurial gauge with the usual accessories for comparing standard gauges, standard weights and measures, instruments for determining specific gravity, and other well-known forms of experimental apparatus would be needed.

Special apparatus and instruments adapted to new methods of investigation and new fields of research would rapidly accumulate, as they might be constructed for special purposes or contributed from outside sources, and would ultimately form a collection of very great value. A small collection of machine tools would be needed for the purpose of preparing materials and of making or repairing apparatus.

4. *The personnel.*—The personnel of this establishment would probably consist of a Director who should be, if possible, familiar at once with the theory and practice of the profession of engineering. and who should also have as large a knowledge as possible of science, particularly in its bearing upon his work. He should have able assistants of similar qualifications, and should be able to appeal to men of science and to practical men alike for advice, with confidence that it would be given and that it could be profited by. Good mechanics to take charge of tools, to aid in preparing apparatus, and to assist in manipulation, and some unskilled labor would complete the list.

Such an institution as has been here briefly described, doing the work which is most immediately required by the various branches of manufacturing industry and of engineering, would be of incalculable benefit to mankind. As remarked by the writer in addressing the Trustees of the Stevens Institute of Technology on this subject, such an enterprise "would give to this country an institution such as has never yet been organized, and one whose value would prove beyond estimation. The accumulation of facts, the valuable application of science, and the directly practical bearing of the work which may be done, would in a comparatively short time be productive of richer results than have been attained in constructive science during many previous years. It would do most effectively that work which has hitherto been too much neglected, the application of scientific knowledge to familiar work and to matters of business. It would do much

to close up the space which so widely separates the man of business from the man of science, and would lead to a far more perfect system of mutual aid than has yet existed."

It would, by aiding the progress of improvement in our methods of work, and by the application of scientific knowledge in practical life, aid in the development of our material resources, lend a new impetus to the industrial enterprises of our people, and assist, to an extent which can probably hardly be conceived, in the promotion of our national prosperity.

A decade of such work as could and should be done, when such facilities are rendered available, may be expected to be more fruitful of practically useful results than a quarter of a century of unsystematic, desultory, and unorganized efforts, such as has hitherto been our only method of acquiring information.

5. *The Stevens Institute of Technology and its Laboratories.*—The convenient location of the Stevens Institute of Technology, its exceptionally complete collections, its special adaptation, in consequence of its organization as a School of Mechanical Engineering and by the training of its officers and employees to such work, has led gentlemen well known in connection with railroad work and with the iron and steel industries to ask whether it would be possible to induce its authorities to inaugurate such an institution as a part of its Department of Engineering.

The evident interest which the plan has awakened among all classes engaged in engineering and mechanical work induced the writer, who had long believed such a laboratory to be one of the necessities of the present time, to address the Trustees upon the subject. This correspondence, in which the case is stated by the writer, and in which the trustees acquiesce in the views presented with an interest and a promptness of action which exhibits a thorough appreciation of the importance of the subject, will be read with interest by every one.

The trustees of the Stevens Institute of Technology have consented to inaugurate a mechanical laboratory, and it is to be hoped that this germ, which is just now commencing its development, may grow into something as noble in itself and as grand in results as its most interested and enthusiastic friends can possibly have anticipated.

It is a pleasure to be able to announce also, that those who are most interested in the matter are taking prompt action in aid of the plan. The American Railway Master Mechanics' Association has its

standing committee, which is ready to do all that lies within its province, and it may be expected to give valuable aid and advice.

The American Society of Civil Engineers have taken similar action, and their committee stands ready to co-operate with other societies and with individuals, and to assist also by advice and active exertion in securing means for the inauguration of this important project.

Leading members of the iron and steel associations and of the press are taking an active interest in the subject, and the plan will be so thoroughly published that it must succeed if the advantages apparent are at all appreciated by those who are to be most directly assisted.

STEVENS INSTITUTE OF TECHNOLOGY.
Hoboken, N. J.

Gramme Machine.—The following is an interesting example of the use of the Gramme machine for lighting purposes. The premises (a large iron foundry in France) are lighted by four lamps, each in electrical union with a Gramme machine, which are placed adjacent to the foundry, and 1700 rotations a minute are effected by means of a steam-engine used in the ordinary work of the factory. Each set of carbons is surrounded by a diffusing globe, so that the light does not appear as blinding points, but as four large shining white globes. The area of the building is about 182 feet by 91 feet, and the lamps are placed at a height of 17 feet above the ground in the corners of a rectangle 70 feet by 46 feet. This arrangement is found to suit admirably; the intensity of the light is nearly constant, and scarcely any shadow falls, on account of the rays from the four lamps crossing each other's paths. The cost, as far as at present ascertainable, is estimated thus :—The carbon poles, 0·250 meter each long = 0·500 m. for every lamp; the section equaling 6 square m.m. The upper carbon is consumed in three hours, the lower in five hours; hence the two may be reckoned as burnt away in four hours, or 0·125 meter per hour per lamp. This, at 1·75 francs a meter, equals 0·22 franc per hour per lamp; and to this must be added an estimate cost of 0·04 franc for driving each machine. The total expense thus becomes 1·04 francs per lamp per hour, *plus* the interest upon the cost of the machine and charge for its wear and tear.

Chemistry, Physics, Technology, etc.

ON THE THEORY OF ILLUMINATING FLAMES.

By Karl Heumann.*

Synopsis of article by Henry Pemberton, Esq.

The views of different observers are widely opposed. Stein believes that the disilluminating effect of the admixture of indifferent gases is the result of dilution only, which permits the oxygen of the surrounding air entering the flame, and transforming all the carbon into carbonic oxide. R. Blochmann is of opinion that the cause of the disilluminating effect of neutral gases, is that a relatively smaller quantity of oxygen comes into contact with the combustible constituents of the flame; and that in the flame of Bunsen's lamp, the entrance of oxygen into the inner zone of combustion causes decomposition of the gas, giving rise to hydrogen and carbonic oxide; therefore, gases that under ordinary circumstances burn without illumination.

Frankland's hypothesis is that the illuminating power of the gas flame specially depends upon its degree of condensation. In opposition to these, F. Wibel shows that a flame rendered nonilluminating by air or an indifferent gas, becomes again brightly luminous when the "burner" is heated to redness. In this case, the dilution of the gases of the flame and the amount of the absorbed air are increased; nevertheless, the flame becomes luminous. Wibel draws conclusions from this, in direct opposition to the views of those above cited, and goes, I think, to the opposite extreme. His thesis urges that it is not the *dilution*, but the *cooling* of the interior of the flame by the entering gases, that robs it of light. This certainly cannot apply to the flame of the Bunsen lamp, for if he is correct, the Bunsen flame should be cooler than the luminous one, whilst daily experience proves that the blue burning flame possesses a much higher temperature.

The oxygen of the admixed air cannot be held to be the cause in this instance; for heating the burner could not alter the relation of the gases, yet the flame thereby becomes luminous. Perhaps it may

*From the *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Sept., 1875.

be suggested that the effect of heating the burner is to restore the temperature that had been lowered by the incoming oxygen, but this is contradicted by the fact that the flame mixed with air is much hotter than the luminous one. The possibility of a lower temperature is therefore not admissible.

It remains therefore to recognize as a fact that the dilution of combustible gases is one important factor, and can alone—without reference to the temperature—disilluminate the flame. It must be further admitted that a mixture of illuminating gas and an indifferent gas requires a higher temperature to become illuminating, than the undiluted gas alone does. Wibel's experiment does not therefore prove that the cooling of the flame is exclusively the cause of the disillumination, for by the admixture of indifferent gases its composition is very materially altered. The truth therefore may well lie between the opposing theories of the different observers, and the disillumination of a flame containing carburets by the introduction of air or an indifferent gas, depends not only upon the cooling effect, but also upon the dilution of the gases of the flame, which dilution may have formed a gaseous mixture needing a higher temperature to burn luminously than the illuminating (un ?) diluted flame itself previously required.

The support that Wibel's theory derived from the behavior of a flame from coal gas and oxygen, is explained by my view in the most convincing manner. As Wibel found, such a flame is extremely difficult to disilluminate, because its temperature in the presence of pure oxygen is an extremely high one. The cooling effect produced by the cold oxygen entering, as well as the absolutely higher temperature required to enable the gaseous mixture to burn luminously, is nearly if not entirely compensated for by the intense heat produced by the concentrated, energetic combustion in the presence of pure oxygen; therefore the disillumination is rendered so much the more difficult. That it ultimately can be produced by a very strong stream of oxygen, and by means of a net of wire gauze, may readily be understood.

The introduction of pure oxygen in a suitable manner into a flame renders it very illuminating by producing an excessively high temperature, whilst the prejudicial dilution that would be caused if air had been used, does not occur. Too much oxygen or too little can produce the same conditions that dilution by an indifferent gas would do;

in the one case the oxygen penetrating the small flame and diluting it excessively, in the other the combustion being too languid to afford the needed temperature.

EXPERIMENTS GIVEN TO SHOW THE EFFECT OF EXCESS OR INSUFFICIENCY OF OXYGEN.

An inverted flask filled with oxygen; into it introduce a small gas flame from the jet of a blowpipe. At first the outer portion of the flame expands enormously, consuming the lighting part of the flame, which decreases until it becomes only a little bright point. After a time, when the products of combustion have diluted somewhat the oxygen, the bright point increases until it reaches the mantle of flame; the brightly shining flame presents then the appearance that it would do in ordinary air. Gradually the products of combustion dilute still more the oxygen, the temperature of the flame sinks still lower, the flame becomes blue, then nearly invisible, and finally goes out.

To show that *cooling* alone can render a flame non-luminous, direct a small luminous gas flame against the bottom of a platinum dish or capsule, so that the flame will spread itself and become *blue*. Thus far, this result cannot be attributed solely to the *cooling* effect, since spreading out the flame might also mix it with the air and dilute it. But if the capsule be heated on the opposite (upper) surface to redness with the powerful flame of a large Bunsen's burner held horizontally, then with the rising temperature of the capsule, the flame beneath it will become brighter and brighter, until it will finally reach its original brilliancy. The capsule must of course be clean and free from traces of soda from the fingers. This proves that the disilluminated flame is again made luminous, simply by the temperature of the metallic plate. If the Bunsen flame be withdrawn, the small gas flame will rêmain luminous for a short time, and then as the metal cools it will become again blue.

In these experiments the question has not here been discussed upon what chemical or physical changes induced by the dilution or cooling, the disillumination depends; nor has the disputed point whether the material that heated to redness becomes luminous—be it carbon or dense vapor—been touched upon; but as concerning the opposing theories whether cooling or dilution is the cause of disillumination, it seems to me decided that at least three different causes, each by itself, can cause disillumination. In most cases, two or all three act simulta-

neously. I give as the result of my observations that *disillumination can occur*—

a. By cooling.

b. By dilution. The mixture of illuminating and neutral gases can only burn luminously when the flame possesses a much higher temperature than the ordinary luminous gas flame.

c. By energetic oxydation of the illuminating material (experiment 1). .

And the restoration of the lighting power will be produced

a. By access of heat (experiment 5).

b. By increase of the temperature of the flame produced by heating mixture of gases or of the indifferent gases before their combustion.

c. By dilution of oxygen with indifferent gases.

ON THE DISTANCE BETWEEN THE FLAME AND BURNER.

R. Blochmann first investigated the phenomenon that the flame does not immediately touch the burner of a gas jet nor the wick of a candle. This is seen more clearly with a small flame than with a large one. As the gas jet is turned down, the relative distance between flame and burner increases. The distance between is much increased when an indifferent gas is mixed, such as nitrogen, carbonic acid, etc. Blochmann thought therefore that the *dilution* was the cause thereof, and explained the fact of the greater distance by stating that a certain fixed proportion must exist between the combustible portion of the gas and the air, and as the diluted gas required more volume for the same combustible quantity, so must a greater volume thereof be mixed with the air before combustion would occur; that is to say, the space between burner and flame must be larger. This somewhat forced explanation of Blochmann is, I think, wrong, for any cold object held in a flame produces a space between the flame and it. This space is the larger, the more diluted the gas.

It is more easily blown out the more it is diluted. A flame diluted with much carbonic acid will stand several inches above the burner, and be blown out with the slightest puff.

If the burner be heated, the flame will approach the burner more and more nearly as the temperature increases. If surmounted with a platinum tube heated to redness, it will approach and attach itself to the bnrner. The opening produced in a diluted gas flame by a

cold iron rod will close in proportion as the rod be heated; if the rod be made red hot, it will close completely. The above may all be noticed in an ordinary gas flame, but not so clearly or decidedly.

The space between the burner of a diluted flame being larger, is dependent upon the fact that the temperature is lower; for at the instant of combustion the evolved heat has to spend itself through the mass of indifferent gas. As the heat of the flame is low, any cool object will extinguish it in its immediate proximity by the further reduction of temperature.

It is thus beyond doubt that in all these experiments the cooling effect produced by the burner or other introduced cold object, is the *sole* cause of the above mentioned intermediate space.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.†

[Continued from Vol. lxx, page 279.]

Siemens' instrument consists essentially of two concentric tubes of glass, the inner tube being lined with tinfoil within, and the exterior coated with the same material without. The inner tube is closed at one end, and is sealed to the outer tube in such a manner that an interval remains between them. The outer tube is drawn out at one end to a thin junction piece, and a similar one is fused to it at the other end. Oxygen circulates in the interval. If the wire ends of the Ruhmkorff's apparatus are brought in contact with the tinfoil coating of the tubes, the intervening space becomes luminous, and the oxygen present is ozonized. Rumine‡ in England and Low in France,§ patented, in 1872, a process for obtaining ozone by blowing cold air into the Bunsen flame. There is no information as to the results of this process.

A patent obtained in England, and specified far from clearly, for

*"Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

†From the *Chemical News*.

‡Rumine, *Ber. Chem. Gesell.*, v, 123.

§Löw, *Ber. Chem. Gesell.*, v, 740.

obtaining ozone by boiling seaweed,* may be mentioned as a curiosity, and also the credulity with which ozone-baths, prepared in this manner, find a ready sale, in spite of, or perhaps rather on account of, their high price. It appears at any rate that an industrial method of obtaining ozone is hitherto an unfulfilled desideratum.

Only the highest branch of industry, that in which justly no price is considered too high, as its object is health, to wit medicine, has found the present method sufficient to allow of the application of ozone. The observation first published by Schonbein, "that the air of towns, and even of well-ventilated rooms in the country contains no ozone," has been subsequently placed beyond the reach of doubt by Andrews,† whilst Schonbein's conjecture as to the connection between epidemics and a deficiency of ozone is certainly unproved.

Latterly Lender has come forward as the advocate of the medical application and efficacy of ozone, which he recommends both as ozonized air and ozonized water in tuberculosis, rheumatism of the joints, glaucoma, asthma, gout, etc.‡ That his exertions have not met with the approval of the profession appears from a discussion of the Berlin Medical Society, Oct. 29, 1873, held under the presidency of Dr. Von Langenbeck.|| Here the use of ozone was defended by Lender alone, and met with zealous opposition. O. Leibreich argued on this occasion that it was impossible to convey into the blood a body so unstable as ozone, which must be decomposed in the respiratory organs. Inhalations of ozone must, therefore, be merely inhalations of pure oxygen, whilst the disinfection of sick chambers may be effected by simpler and better means. Nevertheless, it is necessary to mention here the observations of Schone§ and Houzeau¶ and after working with ozone, its peculiar odor adheres to the hands for some time, as well as to garments of flannel or other tissues. Its decomposition, therefore, appears not to be instantaneous. That the physiological action of strongly ozonized oxygen is very important, appears from the recent experiments of Dewar and MacKendrick.**

**Berl. Chem. Gesell.*, v, 543.

†Andrews, *Nature*, 1874, p. 366.

‡Lender, *Goschen's Deutsche Klinik*, 1872, 1873.

||*Klinische Wochenschrift*, 1873, 588, 589.

§Schöne *Berl. Chem. Ges.* 1873, 1226.

¶Houzeau, *Ann. Chim. Phys.* (4,) xxvii, 16.

**Dewar and MacKendrick, *R. Soc Edinb. Proc.* Session 1873, 1874.

Oxygen ozonized by induction, and containing at most 10 per cent. of ozone, killed small animals which were allowed to inhale it, such as rabbits, mice, and small birds, the latter two in 20 minutes. Respiration was rendered slower, the pulse was enfeebled, and the blood in all parts of the body was rendered venous. This remarkable phenomenon is considered by the observers as due to the high specific gravity of ozone (24th,) which exceeds that of carbonic acid (22d,) and thus retards the diffusion of the latter out of the blood. The irritant action of ozone upon the mucous membrane and its destructive effect upon tissues are recognized both by these observers and by earlier authorities. Redfern considered in 1857 that in his experiments oxygen containing 1-240th of ozone proved fatal to small animals in 30 seconds, producing congestion and emphysema of the lungs after enlargement of the right ventricle.*

Lender has established an ozone manufactory for medicinal purposes. It is announced that ozone inhalations may be had at about 7½d. per cubic foot, or £1 per cubic meter. The method of preparation, and the strength in ozone, are not stated. Ozonized water, according to the degree of concentration, costs from 6d. to 1s. per bottle. This ozonized water was very carefully tested by Carius† with the unfavorable result that in 1000 grms., 0·0087 to 0·0095 grm., or less than 1-1000th per cent. of ozone, was present. Chlorine and hypochlorous acid were not detected. On the other hand, Behrens and Jacobsen‡ say that nothing but hypochlorous acid is found in commercial ozone-water. According to the experiments of Carius, the absorption coefficient of ozone in water is so small that the above-mentioned figures border very closely upon the highest possible quantity.

How great would be the influence of a cheap source of ozone upon manufactures appears at once from the fact that in the nascent state this body oxidizes nitrogen to nitric acid. The presence of the latter body in thunder-rain has long ago been found to result from this circumstance. The manufacture of ozone would, therefore, involve nothing less than the synthesis of this important mineral acid, hitherto only procured from nitre.

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*Andrews, *Nature*, 1874, 366.

†Carius, *Ber. Chem. Ges.* v., 520, *and* vi., 806.

‡Behrens and Jacobsen, *Vierteljahrschrift f, Pr. Pharm. von Wittstein*, xxii, 230, 1873.

That in grass-bleaching and in disinfection by means of ethereal oils we have from time immemorial made use of ozone—generated in the one case by the growth of grass, and in the other by the hydrocarbons—can only serve to intensify our longing for the technical production of ozone. Upon such a process depends the method of bleaching ivory, as it has been conducted since 1850 in Meyer's walking-stick manufactory at Hamburg, and subsequently at other places. The ivory is immersed for weeks in photogen, or other volatile oils, exposed to strong sunshine and to air, whereby the latter is ozonized and bleaches.

The first patent for the application of ozone was recently granted in England. In order to form acetic acid from alcohol without fermentation, the inventors* obtain ozone by blowing air through a flame and bringing it in contact with a current of alcohol. A practical verification of the procedure has not been furnished.

HYDROGEN.

Of the three properties to which the industrial applications of hydrogen are applicable two are of so striking a nature that they cannot have escaped the earliest observers. To them it appeared as the combustible principle, the "volatile sulphur;"† subsequently, it was regarded as the long-sought-for phlogiston,‡ or as the "inflammable air," of which all combustible gases were mere varieties. In modern times, this previously vague knowledge has been rendered definite, recognizing in hydrogen the greatest heat of combustion, and consequently the property of producing the highest degrees of heat and light, properties which met with a practical application at an early date.

The low specific gravity of hydrogen did not escape the earliest observers. Being scarcely ponderable, it excited the idea of imponderable bodies, and its specific lightness, as well as its great heat of combustion, soon met with a striking application.

A third attribute is of a less manifest nature. Occasionally destroying colors, but often obtained without any brilliant and striking phenomena, hydrogen in its nascent state is capable of entering into many combinations, of which it is incapable when pre-existing in a

*Turner and Vanderpool, *Ber. Chem. Ges.*, vi, 1553.

†Lemery, "Memoirs de l'Académie," 1700.

‡Cavendish, 1766.

free state. It liberates chlorine, oxygen, and other elements from their compounds, and takes their place; or it is deposited in compounds not fully saturated, and fills up the vacancies. This attribute is most weighty for the most recent development of chemistry, as well as of great technological importance. Unawares, this property has been made use of for ages. Upon it depends the transmutation of indigo-blue in the vat into indigo-white, and, consequently, one of the oldest and most important branches of the art of dyeing.

(To be continued.)

THE THEORY OF VENTILATION.

Abstract from a paper in the Proceedings of the Royal Society, entitled, "On the Theory of Ventilation—An attempt to establish a positive basis for the calculation of the amount of fresh air required for an inhabited air space," by Surgeon Major F. De Chaumont, M.D.

This paper is the record of a very large number of observations made by the writer, with the assistance of two officers in the British service, in the rooms or wards of barracks and hospitals, chiefly at night, upon a basis of the evidence of the sense of smelling; the observations being accompanied with corresponding examinations of the constituents of the vitiated air. While, however, the "sense of smell" is made the ostensible basis of the theory, it is, in fact, merely used as a measure of the quantity of carbonic acid (CO_2) present, and an exceedingly elaborate set of computations and tables are made to bring into correspondence, and remove the error of observation which was found to attach to the relationship of the smell of odors, which have organic origin, with the presence of inodorous gas. The proportions of Vapor and Humidity, were also considered in the computations very fully, but with the result of extreme divergency, which attaches to the ratio of vapor in a normal atmosphere.

In the words of Doctor De Chaumont: "It is generally admitted that it is organic matter; either suspended, or in the form of vapor, that is the poison in air rendered impure by the products of respiration. It is also admitted, that it is the same substance that gives the disagreeable sensation described as "closeness" in an ill-venti-

lated air space. Although the nature of organic matter may vary to a certain extent, it will be allowed that a condition of good ventilation may be established if we dilute the air sufficiently with fresh air, so that the amount of organic matter shall not vary *sensibly* from that of the external air. Unfortunately, all the methods devised for the determination of organic matter in air, are both difficult and unsatisfactory, so much so, that they are almost practically impossible in a ventilation inquiry. Observations, however, as far as they have gone, seem to show that the amount of organic impurity bears a fairly regular proportion to the amount of carbonic acid evolved by the inhabitant of an air space, and as the latter can be easily and certainly determined, we may take it as a *measure* of the condition of the air space."

Notwithstanding this change of basis of investigation, the observations were really proceeded with on the original method of comparative odor, "closeness," the accuracy of which, does not, from the discrepancies of result, and the extreme profundity of the mathematical operations, in reconciling them with each other, strike one as very satisfactory for general use. The method of observation was as follows: "On first entering the room from the outer air (observations in prisons were not included in the investigation, because of the general difficulty of entering cells directly from the open air), the sensation was noted just as it occurred to the observer. Five grades of sensation were attempted, and denominated "fresh or fair," "not close," "close," "very close," "extremely close." The condition of the last two, however, proved so little dissimilar that they were necessarily merged, so that four grades of terms only remained. The air was then collected in two jars or bottles, and set aside with lime water for subsequent analysis, and the temperature of dry and wet bulb thermometers in the room, at the time of observation, was noted. Samples of the external air, with temperatures at about the same time were taken.

This statement of the nature and extent of each observation; when it is added that the number of observations reached 247, and of chemical analysis reached 473, and that all were tabulated and compared for elimination of varied results; will convey to the reader an idea of the extreme elaboration of study, which will be as satisfactory as an exhibition of the figures made in the steps of calculation. It is obvious, that to preserve any given condition of air in a continuously occupied room, by dilution; the supply of fresh air per given unit of time, must have a constant ratio to the quantity of impurity evolved by the inmates, in the same time; independent

from the size of the room, and equal to the assumed ratio of impurity of condition.* Dr. De Chaumont quotes as authorities for the volume of carbonic acid gas expired per hour, by a sleeping inmate of a room: Angus Smith, 0·405 cubic feet; Dr. Parkes, 0·600 cubic feet; Pettenkofer, 0·705 cubic feet.

Based on his results, and upon these authorities, the following table gives a comprehensive view of Dr. De Chaumont's figures:

Denomination of Sensation.	Limit of carbonic acid (CO_2) found in the air, per cubic foot; being the excess of carbonic acid over the mean external quantity of 0·0004.	Cubic feet of fresh air per inmate per hour needed to preserve the proportion of carbonic acid for the several grades. Angus Smith's estimate, e = 0·405	Dr. Parkes' estimate, e = 0·600	Pettenkofer's estimate, e = 0·705
Fresh, fair, or not close..	0·0001831	2460	3280	3850
Rather close, a little smell	0·0003894	1155	1540	1810
Close....................	0·0006322	710	950	1115
Very close, bad, extremely close......	0·0008583	530	700	825

The estimate of Dr. Parkes is approved by Dr. De Chaumont, and it is stated that the existing Army Regulations of Great Britain contemplate a delivery of 1200 cubic feet per head per hour, in barracks, and his sleeping hours are passed in an atmosphere to be rated between "rather close," and "close," to the sense of smell.

In considering separately the condition of barracks and of hospitals, it was found that in the latter, the "sense of smell" detected respiratory impurity, *accompanied by a far less proportion of carbonic acid.* Grouping the observations on each separately, there were for "fresh, fair, or not close," 0 000196 of carbonic acid present in each unit of volume of air in barracks, to 0·000157 in hospitals. Whence it follows that to preserve relative freshness of the two places, when 3000 cubic feet per hour is requisite for barracks, there will be 4000 cubic feet per hour demanded for hospitals. The condition of the air in the two cases, for less pure ratings in the demonstration of sensation, more nearly corresponded; so that on the whole list they very nearly coincided.

* In the shape of a formula this proportion becomes $d = \frac{e}{q}$ where d = volume of fresh air per inmate per hour, e = volume of carbonic acid expired per inmate per hour, and q = the limit of volume of carbonic acid admissible.

The final conclusions of the paper are as follows:

"*Conditions as to the Standard of good Ventilation.*

Temperature (dry bulb), 63° to 65° Fah.

do. (wet bulb), 58° to 61° Fah.

"N. B.—The temperature should never be much below 60°, but it may be found difficult to prevent its rising in hot weather. In any case, the difference between the two thermometers ought not to be less than 4° and ought not to exceed 5°.

"*Vapor* ought not to exceed 4·7 grains per cubic foot at a temperature of 63° Fah., or 5 grains at a temperature of 65° Fah.

"*Humidity* ought not to exceed 0·73 to 0·75.

"*Carbonic Acid*, respiratory impurity, ought not to exceed 0·0002 per foot. Taking the mean external air ratio at 0·0004, this would give a mean internal air ratio of 0·0006."

In review of this paper, it may be said, especially as applied to this country, that it is scarcely a satisfactory consideration of the necessities of ventilation in continuously occupied rooms. The connection between organic impurities and the presence of carbonic acid, is by no means as simple as here assumed. Recognizing that organic substances are either in suspension in the humidity or vapor in the air, or bear some more intimate relation to the humidity or vapor; in other words, that *they* are *not* independent gases, following the laws of diffusion; then, it follows, that *their* rate of absorption or diffusion varies in some ratio (perhaps not directly as) with that of the humidity or vapor.

The rate of diffusion of a vapor as compared with the rate of diffusion of carbonic acid, is exceedingly high. Taking, for instance, the average temperature between that of expired breath (90°), with that assumed by Dr. De Chaumont for the room, (65°) = $77\frac{1}{2}$°; the tension of aqueous vapor is so low that its specific gravity becomes about 0·0196, while that of carbonic acid is 1·5290. As the rates of diffusion of the two gaseous bodies vary nearly as the reciprocals of the square roots of their densities; equal volumes of vapor, or of carbonic acid, would be diffused, in the ratio of 7·14 to 0·81. The best conclusion the writer of this article can reach, favors the presumption that about equal weights of moisture and of carbonic acid are evolved (in all ways) by the person; at rest or otherwise, in a uni of time. The volumes, therefore, to be dispersed are, in con-

sequence of the extreme levity of the vapor, as 78 to 1. It consequently requires 8·8 *times longer* to diffuse the vapor, than the time which is needed to diffuse the carbonic acid; and this ratio is further increased, by the difference of the relative rates of diffusion which would ensue from the presence of the different proportions of the gaseous bodies already in the air, to 10 or 12 times longer.*

Now, although the conditions of humidity for each observation have been carefully noted, compared and averaged in the paper, the final resulting ratios of organic impurity to carbonic acid present (whether the sense of smell be allowed as sufficiently accurate test, or the chemical analysis be accepted as the ground of the theory of ventilation) apply only to the average temperatures of 63° to 65° Fah., and corresponding humidity of 73 to 75 per cent. These conditions may subsist in England, or at least may not be differed from to the degree of affecting the average result, but in this country as in Northern or Eastern Europe, neither the external or internal temperature is supposable.

It would also have been much more satisfactory, if, with all the labor and care of making these observations, an estimate of real quantity of fresh air accompanying them had been recorded. It is stated to be sure, that "the army regulations contemplate 1200 cubic feet per inmate per hour, but practical inquiry has shown that this amount is generally fallen short of," but nothing is said from which the absolute quantity of fresh air, at any time of observation, can be inferred. The writer of this article, after inspection of the best English and French hospitals, is confident that this quantity of air is not usually supplied whenever the external temperature ranges below 50° Fah.

With little difficulty, it would be possible to arrange a room in England (or even in this country), from which; without change of air, and without removal of organic impurities, to any large extent; the carbonic acid would disperse freely. Conceive a room with the windows and doors tight and closed, and without opening at the bottom, but with an ample ventilation in the ceiling. This

* It must be noted that diffusion of vapor (when in gaseous, not vesicular condition) probably follows the laws of diffusion of gases, while evaporation from a moist surface is influenced (accelerated or retarded) in ratios of the tension of the vapor in contact with the surface; ceasing altogether when the tension is that due a saturated vapor, of the temperature of the moist surface.

ventilation might be guarded by gauge screens to preclude both currents, if the external and internal temperatures differed materially, but at mean temperature of nine months in the year, in England, no such guarding will be needed. In such a room no circulation of air from the outside would take place, while following the laws of diffusion, the ratios of carbonic acid and of nitrogen, after reaching some maximum of no large proportion; not much, if any, above the condition of "*fresh*," would become constant; while with the degree of saturation usual in England for nine months in the year, very little of the vapor of exhalation would be dispersed, but would merely be condensed on the walls and windows of the room in streams—absorbing in liquid form, the offensive organic substances.

This extreme suppositious case is a *type* of what actually occurs in hospitals in England, *in degree.* A limited ventilation is provided by inadequate supply, while ample discharge outlets admit of escape of carbonic acid by diffusion. Except the hospitals for the insane, the same defect subsists in general in hospitals, in this country; although the immense dryness of our winter air so promotes this diffusion of vapor, as to make our winter ventilation comparatively tolerable.

The assertion that 50 to 70 cubic feet of air per inmate per minute is requisite for dormitories in barracks or hospitals *might* be allowed to go unquestioned on the ground of the more of a good thing the better. Of course, if this quantity be taken as the *night* ventilation, at least one-half more is needed for the day supply of a sick ward. But any recommendation which carries with it an impracticability of performance, is likely to be as productive of harm as if it were absolutely wrong of itself. It is not necessary for the health of well or sick that they should exist in currents of air; it is not possible in mid-winter, in our climate, or in England to provide and heat such quantities. It is not feasible to arrange a building for any moderate or reasonable cost to admit them, and it may, without argument, be asserted that it is not desirable. The old device of the geometrician was "reductio ab adsurdum," and it will apply to-day. Any propositions which lead to such variance from possibilities must have erroneous data.

The probable solution is, let us get rid of the organic substance, and endure a little larger proportion of carbonic acid. We know the former to be deleterious and the latter to be innoxious. B.